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Coal Surface Mining Reclamation Costs in the Western United States

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 8737

Coal Surface Mining Reclamation Costs in the Western United States

By Franklin H. Persse, David W. Lockard, and Alec E. Lindquist

March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

U.S. BUREAU OF MINES

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COAL SURFACE MINING RECLAMATION COSTS
IN THE WESTERN UNITED STATES

by

Franklin H. Persse,[1] David W. Lockard,[2] and Alec E. Lindquist[1]

ABSTRACT

The Bureau of Mines estimated reclamation costs for 13 surface coal mines in nine States west of the Missisisppi River. With the exception of the Pacific Coast coal province, at least one mine in each of the western coal provinces was studied. Cost estimates were made using standard estimating procedures from data obtained from company records, interviews with industry personnel, and onsite observations. Estimated costs are presented in four categories which represent the four phases of mined-land reclamation: (1) Design, engineering, and overhead; (2) bond and permit fees; (3) backfilling and grading; and (4) revegetation. Estimated costs as of the first quarter of 1976 are expressed as averages and ranges in terms of per acre, per ton of coal produced, and per million Btu.

Total reclamation costs ranged from \$860 to \$7,200 per acre, from 6 to 84 cents per ton, and from 4 to 35.3 mills per million Btu. A mine in the Northern Great Plains coal province (Region D) showed the highest per acre cost whereas mines in part of the western region of the Interior coal province (Region A) experienced the greatest per ton and per million Btu cost.

The high cost of reclamation in the Western United States is reflected in the backfilling and grading category, particularly in the cost of topsoil removal and subsequent replacement as required by individual State reclamation regulations.

INTRODUCTION

The Bureau of Mines conducted this study to determine, within reasonable limits, the costs of reclaiming surface-mined coal lands at active mines in the Western United States, exclusive of Alaska. Data were obtained from onsite observations of 13 mines in nine States, from interviews with industry personnel both at the mines and in field or home offices, and from company records. Although some of the data obtained were of a confidential nature, they are presented here in a manner to avoid disclosure.

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[1] Mining engineer, Intermountain Field Operations Center, Bureau of Mines, Denver, Colo.

[2] Mining engineer (now State Liaison Officer), Bureau of Mines, Boise, Idaho.

The work was initiated late in 1974 with data being gathered until April 1975. Using standard estimating procedure, reclamation costs were estimated, then updated to reflect costs as of the first quarter of 1976.

Information Circular 8695, Coal Surface Mining Reclamation Costs, Appalachian and Midwestern Coal Supply Districts, published in 1975, presented mined-land reclamation costs at selected surface coal mines east of the Missisippi River. Although equipment and labor costs used for this publication are those current in the first quarter of 1976 and those used for IC 8695 were of 1974, general comparisons of mined-land reclamation costs throughout the United States may be made.

ACKNOWLEDGMENTS

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GENERAL INFORMATION

The term "mined-land reclamation" has been used indiscriminately. It referred to any process for rehabilitating land disturbed by surface mining from seeding only to returning spoiled land to near its original condition. Presently the term "mined-land reclamation" refers to returning the disturbed land to a condition and/or use equal to or higher than that prior to mining. Local, State, and/or Federal regulations generally govern the reclamation and, where applicable, such regulations were a guide for this study.

Four regions, designated A, B, C, and D were selected for this study. Each region is within a coal province (12)[3] west of the Mississippi River (fig. 1).

1. Region A is the coal mining area of Kansas and Missouri in the western region of the Interior coal province which includes parts of the States of Arkansas, Kansas, Iowa, Missouri, and Oklahoma.

2. Region B is the east Texas part of the Texas region of the Gulf coal province. The Texas region is in east and south Texas, southern Arkansas, and northwest Louisiana.

3. Region C consists of two locations. One is the Four Corners area of Arizona and New Mexico and the other is Routt County, Colo., both in the Rocky Mountain coal province, which includes parts of the States of Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming.

4. Region D is the Northern Great Plains coal province, in eastern Montana, western North Dakota, northwestern South Dakota, and northeastern Wyoming.

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[3] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

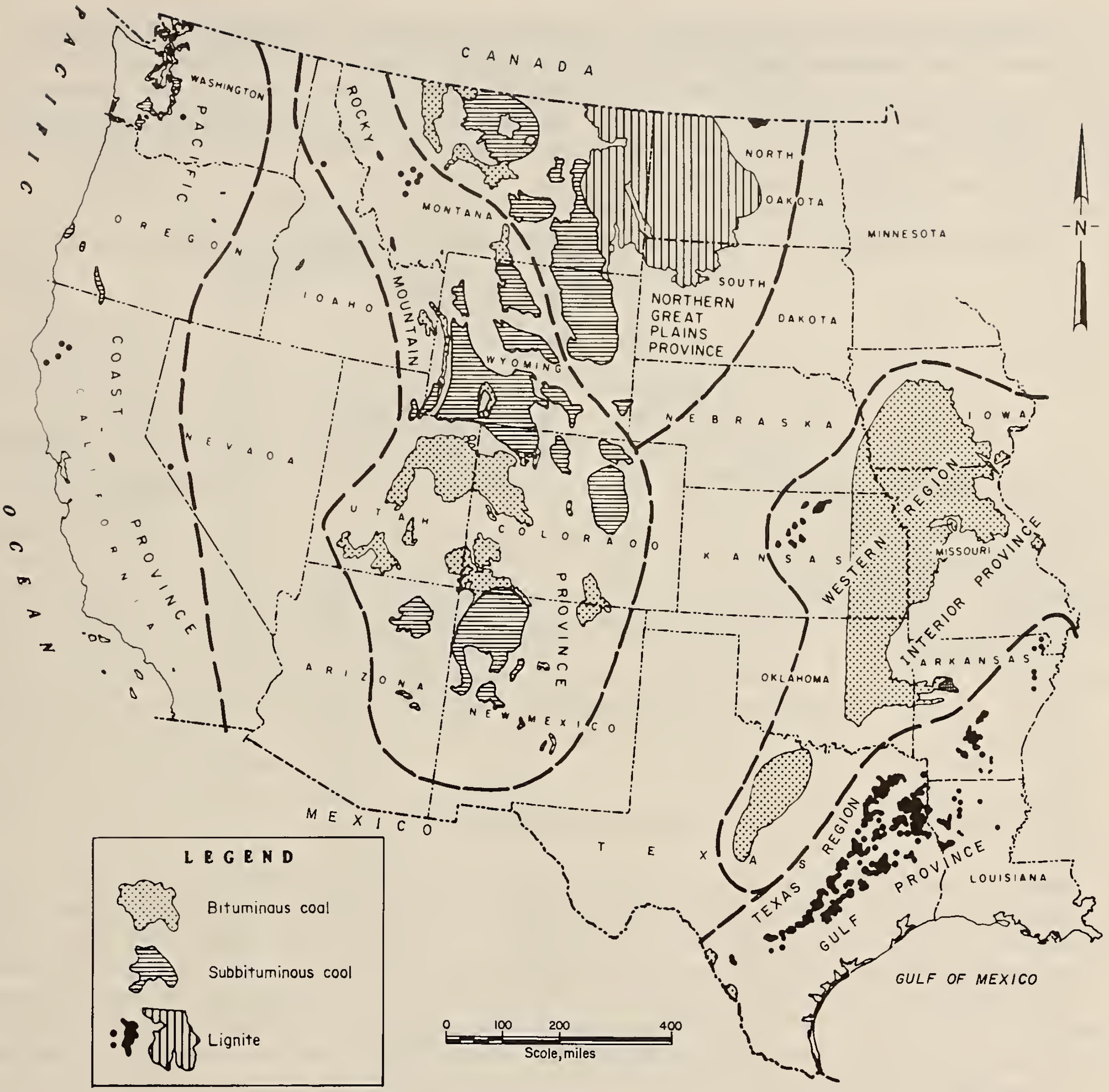

FIGURE 1. - Coal provinces in the contiguous Western United States. Adapted from USGS Coal Map of the United States, 1960.

Excluding Alaska, coal is produced in the following States west of the Mississippi River: Arizona, Arkansas, Colorado, Iowa, Kansas, Missouri, Montana, New Mexico, North Dakota, Oklahoma, Texas, Utah, Washington, and Wyoming. In 1974, production from these States accounted for 91.2 million tons or 15.1 percent of the Nation's output. In 1975, the same States accounted for 110 million tons of coal or 17.0 percent of the Nation's output. Much of the increased output can be attributed to a greater quantity of coal produced from surface mines. In 1975, 122 surface mines produced 98.2 million tons of coal, or 89.1 percent of all coal mined in the Western States (table 1). However, 96.9 million tons or 98.7 percent of the surface mine output was from 66 mines producing 100,000 or more tons of coal. Therefore, it can be estimated that approximately 99 percent of the land that was disturbed by surface coal mining took place at the 66 largest mines. Using this reasoning, only those mines producing more than 100,000 tons of coal annually were studied, and the majority of the mines studied had an annual output of more than 500,000 tons of coal.

TABLE 1. - Number and production of bituminous coal and lignite mines, by State, size of output, and type of mining--1975[1]

(Thousand tons)

State	100,000 tons and more		Less than 100,000 tons		Total[2]	
	Number of mines	Quantity	Number of mines	Quantity	Number of mines	Quantity
Arizona:						
Strip..........	2	6,986	-	-	2	6,986
Underground.....	-	-	-	-	-	-
Arkansas:						
Strip..........	2	W	6	W	8	488
Underground.....	-	-	-	-	-	-
Colorado:						
Strip..........	9	4,648	6	125	15	4,773
Underground.....	9	3,144	9	302	18	3,446
Iowa:						
Strip..........	-	-	8	259	8	259
Underground.....	1	W	1	W	2	363
Kansas:						
Strip..........	2	W	2	W	4	479
Underground.....	-	-	-	-	-	-
Missouri:						
Strip..........	8	5,534	5	104	13	5,638
Underground.....	-	-	-	-	-	-
Montana:						
Strip..........	5	22,035	3	19	8	22,054
Underground.....	-	-	-	-	-	-
New Mexico:						
Strip..........	4	8,022	-	-	4	8,022
Underground.....	1	764	-	-	1	764
North Dakota:						
Strip..........	8	8,501	2	14	10	8,515
Underground.....	-	-	-	-	-	-
Oklahoma:						
Strip..........	9	2,384	22	488	31	2,872
Underground.....	-	-	-	-	-	-
Texas:						
Strip..........	4	11,002	-	-	4	11,002
Underground.....	-	-	-	-	-	-

See footnotes at end of table.

TABLE 1. - Number and production of bituminous coal and lignite mines, by State, size of output, and type of mining--1975[1]--Continued

State	100,000 tons and more		Less than 100,000 tons		Total[2]	
	Number of mines	Quantity	Number of mines	Quantity	Number of mines	Quantity
Utah:						
Strip...........	-	-	-	-	-	-
Underground.....	14	6,639	6	322	20	6,961
Washington:						
Strip...........	1	W	1	W	2	3,730
Underground.....	-	-	1	13	1	13
Wyoming:						
Strip...........	12	W	1	W	13	23,369
Underground.....	2	W	2	W	4	436
Western States:						
Strip...........	66	96,922	56	1,265	122	98,187
Underground.....	27	11,102	19	881	46	11,983
Total	93	108,024	75	2,146	168	110,170

W Withheld to avoid disclosing individual company data.

[1] States west of Mississippi River, exclusive of Alaska.

[2] Data may not add to totals because of independent rounding.

Source: U.S. Bureau of Mines.

ESTIMATING PROCEDURE

Data from the selected mines were gathered during the last quarter of 1974 and the first quarter of 1975. Where applicable, the criteria used for gathering data were the mined-land reclamation regulations, effective at the time the operations were visited. Since then, some States have revised their regulations while others have instituted new regulations. Such changes usually create increases in mined-land reclamation costs, but changes in regulations after data were gathered were not considered. For operations in States not having regulations at the time the data were gathered, the cost estimates were based on observation of the work being done.

Costs used for equipment, labor, and overhead expenditures were those current in the first quarter of 1976. Sources of equipment ownership and operating costs include the following: The Caterpillar Performance Handbook (2), equipment manufacturers and dealers, mine operators, and company brochures and papers available to the public. At some operations, confidential costs were obtained and were used where applicable. However, such costs were updated, by standard estimating methods, to conform to those of the first quarter of 1976.

Estimates for the cost of labor were made using the United Mine Workers wage scales, effective during the first quarter of 1976.

Accounting procedures for costing reclamation and other environmental related work varied with the mining companies. In this study, reclamation costs are presented in four categories: (1) Design, engineering, and overhead; (2) bond and permit fees; (3) backfilling and grading; and (4) revegetation. The categories were selected as a means of presenting the estimated reclamation costs with reasonable accuracy and uniformity and were not intended to be those of any one mining company. The costs for each category were based on the number of acres reclaimed annually. The average and range of costs are shown in table 2 as the cost per acre, the cost per ton of coal produced, and the cost per million Btu. The cost per ton and cost per acre constitute a ratio of the annual reclamation cost to the annual coal production, although the area of land disturbed or reclaimed annually is greater than the area mined.

Reclamation costs vary at any single operation as well as from one site or region to another. Table 3 shows the ranges of variation as a percentage of the total reclamation costs. The many variables that affect reclamation cost differences include but are not limited to terrain, soil, vegetation, type and thickness of overburden, coalbed thickness, ground and surface water, climate, size and type of equipment used, method of mining, reclamation laws and regulations, and the individual operator's method of reclaiming the land.

Design, Engineering, and Overhead

Costs for design, engineering, and overhead include the following: (1) Development of the reclamation plan; (2) preparation of periodic environmental reports; (3) supervision of the reclamation work; (4) engineering and surveying for environmental protection; (5) water quality protection and monitoring; (6) overhead of environmental activities; (7) outside environmental consultants; (8) to the extent applicable a proration of surveying and mapping the mine site; (9) dust control associated with reclamation; and (10) miscellaneous expense.

In the future, almost all of the surface mines in the West will have added costs for such items as monitoring the climate and ambient air; making archaeological, historical, floral, faunal, and soil surveys; and contributions to environmental impact statements. Such charges were not included in the cost of design, engineering, and overhead because the mines surveyed were in operation before such items were required, and mining had not progressed to lands where these items were a requirement for obtaining a lease or permit.

TABLE 2. - Estimated averages and ranges of mined-land reclamation costs

Item	Region A, sites 1-6[1]	Region B, site 1	Region C, sites 1 and 2	Region C, site 3	Region D, site 1	Region D, site 2	Region D, site 3
Design, engineering and overhead:							
Average, per acre	$930	$440	$775	$685	$410	$570	$230
Range, per acre	$510-1,910	$420-480	$480-1,070	$625-750	$350-730	$350-650	$200-400
Average, per ton	0.21	0.05	0.05	0.07	0.01	0.06	<0.01
Range, per ton	0.14-0.29	0.04-0.05	0.04-0.06	0.06-0.08	0.01-0.02	0.04-0.07	<0.01-0.01
Average, per million Btu	0.0092	0.0028	0.0029	0.0029	0.0007	0.0045	0.0004
Range, per million Btu	0.0058-0.0138	0.0025-0.0031	0.0024-0.0033	0.0026-0.0031	0.0006-0.0010	0.0027-0.0051	0.0003-0.0006
Bond and permit fees:		([2])	([3])				
Average per acre	35		25	35	60	30	70
Range, per acre	30-45		0-80	25-45	50-70	20-40	60-100
Average, per ton	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Range, per ton	<0.01-0.01		0.0-<0.01	<0.01-<0.01	<0.01-<0.01	<0.01-<0.01	<0.01-<0.01
Average, per million Btu	0.0003		<0.0001	0.0001	0.0001	0.0002	0.0001
Range, per million Btu	0.0002-0.0005		0.0-0.0002	<0.0001->0.0001	0.0001-0.0002	0.0001-0.0002	0.0001-0.0002
Backfilling and grading:	([4])						
Average, per acre	1,500	630	1,680	1,430	4,410	2,420	2,050
Range, per acre	1,060-2,170	410-2,470	1,250-[5]3,420	990-1,970	3,700-6,200	2,200-5,500	1,800-2,900
Average, per ton	0.38	0.07	0.09	0.15	0.14	0.27	0.06
Range, per ton	0.29-0.52	0.04-0.27	0.08-[5]0.18	0.10-0.20	0.12-0.20	0.24-0.61	0.05-0.09
Average, per million Btu	0.0167	0.0045	0.0046	0.0067	0.0079	0.0190	0.0038
Range, per million Btu	0.0123-0.0201	0.0035-0.0179	0.0034-[5]0.0068	0.0045-0.0090	0.0066-0.0111	0.0173-0.0433	0.0034-0.0054
Revegetation:							
Average, per acre	45	35	350	35	170	120	150
Range, per acre	25-75	30-45	110-470	30-45	100-200	100-150	140-200
Average, per ton	0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01
Range, per ton	0.01-0.02	<0.01-<0.01	0.01-0.02	<0.01-<0.01	<0.01-<0.01	0.01-0.02	<0.01-<0.01
Average, per million Btu	0.0005	0.0002	0.0007	0.0002	0.0002	0.0009	0.0002
Range, per million Btu	0.0002-0.0009	0.0001-0.0003	0.0002-0.0009	0.0001-0.0002	0.0001-0.0003	0.0008-0.0012	0.0002-0.0003
Total reclamation:[1]							
Average, per acre	2,510	1,105	2,830	2,185	5,050	3,140	2,500
Range, per acre	1,625-4,200	860-2,995	1,840-5,040	1,670-2,810	4,200-7,200	2,670-6,340	2,200-3,600
Average, per ton	0.60	0.12	0.15	0.22	0.15	0.34	0.07
Range, per ton	0.44-0.84	0.08-0.33	0.12-0.26	0.16-0.28	0.13-0.23	0.29-0.70	0.06-0.10
Average, per million Btu	0.0267	0.0075	0.0082	0.0099	0.0089	0.0246	0.0045
Range, per million Btu	0.0185-0.0353	0.0061-0.0213	0.0060-0.0112	0.0073-0.0124	0.0074-0.0126	0.0209-0.0498	0.0040-0.0065

[1] The lowest and highest costs, in the range of costs, are not necessarily from the same mine.

[2] At the time Region B was studied neither a bond nor a permit was required.

[3] The State of Arizona has no law that requires a bond or permit for mined-land reclamation. All mining is on Indian land and reclamation regulations are included in the lease agreement.

[4] Includes the rough and fine grading of the spoil from the box and intermediate cuts and ramps, construction of dams in final cuts, rock removal, and road rehabilitation.

[5] Where available, topsoil is removed and replaced, which more than doubles the backfilling and grading costs for these areas compared to areas with no topsoil.

TABLE 3. - Normal ranges of item costs as a percentage of total mined-land reclamation costs

Item	Region A, sites 1-6	Region B, site 1	Region C, sites 1 and 2	Region C, site 3
Design, engineering and overhead..	30-45	16-48	20-30	25-38
Bond and permit fees.............	1- 2	-	0- 2	1- 2
Backfilling and grading..........	50-65	48-83	56-68	60-70
Revegetation.....................	1- 2	2 -3	6-12	1- 2
	Region D, site 1	Region D, site 2	Region D, site 3	
Design, engineering and overhead..	8-10	10-18	9-12	
Bond and permit fees.............	1- 2	1- 2	2- 3	
Backfilling and grading..........	85-90	75-85	80-85	
Revegetation.....................	3- 4	2- 7	5- 7	

Bond and Permit Fees

Except for Arizona and Texas, all of the Western States having surface coal production had bonding requirements in effect prior to the study. The amount of the bond varied widely. A bond can be cash, negotiable securities, a savings account assignment, or it can be a purchase from a surety company. The latter is the common procedure, and the rates are variable. Maximum rates are generally established by State insurance commissions and seldom exceed $15 per $1,000 of bond.

Although a bond remains in effect for many years, the annual per acre bonding cost was estimated using the total bonding cost for 1 year divided by the number of acres disturbed in 1 year.

A permit in some States is called a license. Permit or license periods vary from State to State, ranging from 1 year to 3 to 5 years, to the life of the operation. Fees for a permit or license also vary. All States that required a permit had a basic fee that ranged from $25 to $100, and many States add a per-acre fee ranging from $5 to $25.

A permit or license authorizes mining on a specified parcel of land described therein. However, the authority for a State to issue such a permit or license is the statute requiring reclamation of lands disturbed by surface mining. Therefore, the fee for a State permit or license was considered a reclamation cost. Charges for Federal or local permits were considered to be a mining cost and were not included as a reclamation cost.

Permit or license fee per acre was estimated using the annual charge divided by the number of acres disturbed annually.

Backfilling and Grading

The category of backfilling and grading includes costs in addition to those normally expected. Costs covered in this category are as follows: (1) Removal of vegetative cover from the area to be mined when its removal is necessary for topsoil salvage; (2) removing and stockpiling topsoil; (3) backfilling troughs, haulage ramps, and final cuts with spoil; (4) rough and fine grading of spoil; and (5) removing topsoil from stockpiles and replacing it uniformly on the graded spoil.

Removal of the vegetative cover is required only when the trees and/or brush interfere with the removal of topsoil, overburden, or both. It is the exception at western surface coal mines to remove the vegetative cover separately. At the mines studied, vegetation was removed with the topsoil where topsoil was salvaged or with the overburden at those operations not salvaging topsoil. Now, however, in Kansas it will be necessary to remove trees and brush in areas where topsoil cannot adequately be removed otherwise.

At the time the data were gathered, only four of the nine States visited required salvaging and replacing topsoil. Requirements for the amount of topsoil or other suitable growth material to be salvaged vary. However, the quantity of topsoil available for salvage also varies from place to place.

In general, two procedures are used for removing and replacing topsoil. It is either removed and stockpiled to be replaced at a later time, or it is removed from an area to be mined and placed upon the graded spoil on an area previously mined. The latter procedure is the least expensive because it eliminates double handling.

At the large western mines, draglines are predominately used for overburden removal. Shovels are the next most prevalent, followed by shovel and trucks combination. At least two operations are trying bucket wheel excavators in combination with other equipment. However, scrapers and bulldozers are often used to remove high points and for preparing a working place for a drill or dragline. Scrapers are also used at many small operations to remove all of the overburden, and almost all of the mines that are removing and replacing topsoil use scrapers for this purpose. Overburden usually can be removed at less cost using a dragline or a shovel than by using scrapers.

Topsoil is the uppermost layer of the overburden. Consequently, where topsoil is not salvaged, it becomes mixed with the remainder of the overburden as it is removed and spoiled. Therefore, where topsoil is removed for the purpose of reclamation the charges for its removal should be allocated between mining and reclamation. Apportioning charges between mining and reclamation can be complex. Reclamation costs for topsoil removal should be the difference between the cost of removing the topsoil minus the cost of removing the topsoil portion of the overburden if the topsoil had not been salvaged.

At many of the mines in the West where topsoil is salvaged, the surface is dry and hard, and often must be ripped before it can be removed with scrapers. In addition, push tractors generally are used to assist with loading the scrapers. The operation of each additional piece of equipment increases the cost of removing topsoil, but without the assisting equipment removal could be even more costly.

Backfilling troughs, haulage ramps, and final cuts can be defined as the process of moving spoil from the peaks and ridges to the troughs and other low places until the approximate final surface configuration is obtained. To obtain a rolling topography or a flat surface by backfilling the troughs, the quantity of spoil and the distance spoil must be moved depends upon the width of the pit from which the coal was extracted. The distance is directly proportional to the pit width, and the quantity is proportional to the square of the pit width (6).

When the approximate final surface configuration is approached the area is rough-graded to the final configuration.

Generally backfilling and rough grading are accomplished with bulldozers; however, some operations use scrapers and draglines.

Fine grading readies the spoil surface for either soil preparation or topsoil replacement; it removes low places and small humps and ridges. Various types of equipment are used; usually, it is whatever equipment that the mine operator believes will do the best job at the least expense. Motor patrols, bulldozers, or tractor pulled drags or floats are commonly used. Surface rock removal, where necessary, is generally considered a fine-grading procedure; however, at some operations surface rocks are removed after the vegetation becomes fairly well established. Rocks are removed from the surface by hand-picking and/or with front-end loaders. A few mines are experimenting with mechanical rock pickers.

Where topsoil is salvaged and reused, it is placed uniformly on the fine-graded spoil, usually with scrapers. The time spent for fine grading may be reduced if the quantity of topsoil is sufficient to fill small depressions and cover small rocks and humps.

Revegetation

Revegetation includes part or all of the following procedures: Soil preparation, seeding and/or planting, reseeding and/or replanting, and irrigation.

Preparation of the spoil or topsoil was not undertaken at all mines, but where it was undertaken it consisted of one or more of the following procedures: Disking, gouging, harrowing, mulching, adding soil conditioners, and fertilizing.

The appropriate season(s) for seeding and/or planting is determined by the climatic conditions at a mine site. At most of the western mines, the usual methods of seeding are drilling or broadcasting. An aircraft is sometimes used for broadcasting. Bermuda grass is sprigged in Texas. Occasionally trees and shrubs are planted, particularly if a wildlife refuge is to be established on the reclaimed land. Hand-planting is the method commonly used.

Occasionally a temporary crop is seeded to prevent erosion or to add vegetative material to the soil. Annuals that germinate and grow rapidly are used, and are either seeded separately or with the permanent cover. When seeded separately, the green or mature crop is disked into the soil to act as a conditioner or fertilizer.

No operation visited had ever experienced a complete failure in establishing vegetation; therefore, reseeding or replanting was required only on places that did not produce sufficient cover from the original seeding or planting. Such bare or sparsely covered areas may be the result of toxic soil, seed or young plants eroded by wind or water or destroyed by man or animals, areas missed by original seeding or an insuffïcent amount of soil moisture to germinate seed.

Irrigation to start and to establish a vegetative cover is being tested at some operations in arid areas. However, it has not been in use long enough to determine if the vegetation, once established, will survive when the irrigation is terminated. In arid areas, water is costly and, coupled with high labor and irrigation equipment costs, the result is high revegetation costs. Should irrigation prove successful the period for establishing required vegetation could be shortened and the threat of erosion reduced.

DESCRIPTION OF THE REGIONS

All or parts of five of the Nation's six coal provinces are west of the Mississippi River (12), and 13 surface mines in four provinces were selected for study. Mines were selected so that the greatest variety of climatic, mining, and regulatory conditions could be studied. It was not possible, however, to include all of the variations in conditions and mining methods that would be encountered at each and every surface mine in the West. Therefore, the following four regions, each part of a coal province, were studied:

1. Region A is in the western region of the Interior coal province, which includes parts of Arkansas, Kansas, Iowa, Missouri, and Oklahoma. Mines in Kansas and Missouri were studied.

2. Region B is in the Texas region of the Gulf coal province in east and south Texas, southern Arkansas, and northwest Louisiana. Lignite mines in east Texas were studied.

3. Region C is in the Rocky Mountain coal province which includes parts of Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming. Mines in Arizona, Colorado, and New Mexico were studied.

4. Region D is the Northern Great Plains coal province which is in eastern Montana, western North Dakota, northwestern South Dakota, and northeastern Wyoming. Mines in Montana, North Dakota, and Wyoming were studied.

Region A

Currently, 14 surface coal mines with annual outputs ranging from less than 10,000 tons to more than 1 million tons are operating in Region A (fig. 2). High-sulfur, medium- to high-volatile bituminous coal is produced by area mining and is used primarily for electric power generation.

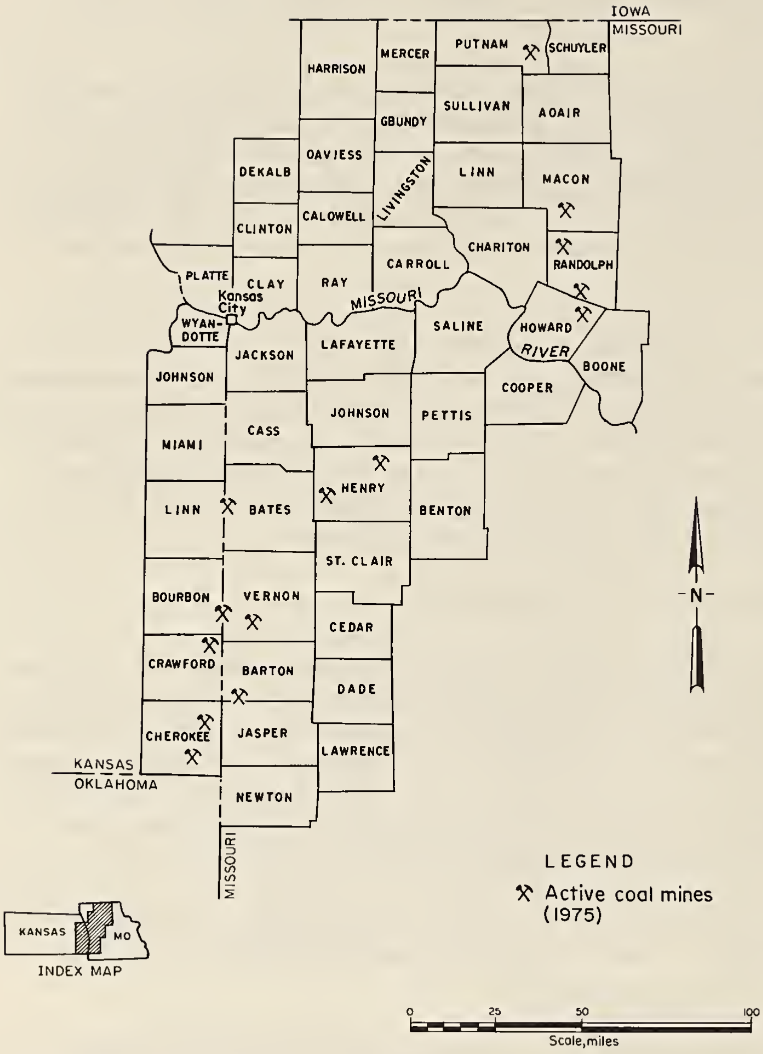

FIGURE 2. - Active coal mines in Kansas and Missouri.

Reclamation cost data for the region were gathered by visiting six mines, each capable of producing more than 100,000 tons annually. The climate, topography, vegetation, land use, mining, and reclamation methods at the various operations, as well as the State reclamation regulations, are sufficiently similar for a general description.

The climate in the study area is temperate. Average annual precipitation, mostly rain, ranges from 35 inches in the north to 40 inches in the south. Throughout the region the prevailing wind is southerly, and midsummer temperatures of 100 degrees or more are reached 10 to 15 days each year.

The topography is flat to rolling prairie with occasional low hills. Elevation changes in the study area are gradual ranging from about 650 to 1,050 feet. South of the Missouri River, rock exposures are predominantly sedimentary and of Pennsylvanian age, but north of the river the surface is dissected, Pleistocene glacial till.

Predominant trees, usually small, are second-growth oak and hickory. Grasses are mainly bluestem prairie grasses.

Agriculture--small grains, livestock, dairy products, and poultry--is the dominant land use. About 10 percent of the farmland is used for row crops, the remainder for hay and pasture. Many land occupants are part-time farmers, and most farms are less than 180 acres.

Mining coal by surface methods began more than 50 years ago; now all production is obtained from surface operations. Until recently, almost all of the disturbed land was left as mined. Water stored in final pits on the old unreclaimed land, as well as on reclaimed land, is used for stock ponds, fishing, waterfowl refuge, domestic and industrial purposes, and recreation (fig. 3). Much of the land left as mined has revegetated and is used for wildlife habitat, pasture, and recreation (fig. 4). Some of the unreclaimed land has been sold or donated for public recreation areas and has a high visitor-day use (fig. 5).

In 1975, about 2,000 acres of land in the study area were mined, yielding 5.8 million tons of coal. Maximum highwall heights range from 40 to 100 feet, with slopes ranging from approximately one-half to three-fourths to 1 (from 64 to 53 degrees from horizontal). Often the contour of the coalbed is similar to that of the rolling surface, and the economic limit is reached only where low hills are encountered. Maximum stripping ratios range between 20 to 1 and 30 to 1. Low-stripping ratios are achieved where coalbeds total 4 feet or more in thickness; high ratios are encountered where recoverable coal thins to as little as 15 inches. Pit widths vary but seldom exceed 110 feet. The angle of repose for recently placed spoil ranges from 35 to 39 degrees.

Except for the soil and glacial drift, the overburden and coalbeds are of Pennsylvanian age. In the southern part of the study area, overburden mainly consists of soil ranging in thickness from 0 to 18 inches, limy shale, shale, and limestone. Shale in the overburden and partings between coalbeds, when exposed, weathers to clay. Pyrite, when present, can acidify surface water. Typical overburden north of the Missouri River, in the glaciated area, includes soil material that is underlain with limy shale, shale with a pH of less than 7, limestone, and calcareous sediments that are capable of supporting vegetation. The soil material usually is about 30 inches thick, but in a few places it is as much as 20 feet thick.

No aquifers are encountered in mining, but occasionally the workings intersect a seep.

Surface water must be diverted around or pumped from the working area. Settling ponds, usually dammed final cuts, receive this water to prevent polluting watercourses with sediments.

Although salvaging topsoil is now required in Kansas, it was not required at the time the mines were visited. However, some mines spoil overburden so that acid-forming material or other materials not suitable for plant growth will be buried when the spoil is graded. For example, at an operation where two coalbeds were mined, overburden from the top coalbed was spoiled away from the lower coalbed to allow the acid-forming parting from between the coalbeds to be placed in the bottom of the previous cut (fig. 6). Then, when the spoil is graded, the parting is buried.

Bulldozers are used for backfilling and for pushing or pulling a drag for final grading. Occasionally a scraper is used to cover exposed toxic spoil with nontoxic material. Small, farm-type, front-end loaders assist handpickers where rock removal is required. Between 10 and 11 percent of the disturbed land is reclaimed by impounding water in the final cuts. In Kansas, the reclaimed land is virtually leveled because the law requires that no slope exceed 25 percent, and slopes between 15 and 25 percent cannot exceed a

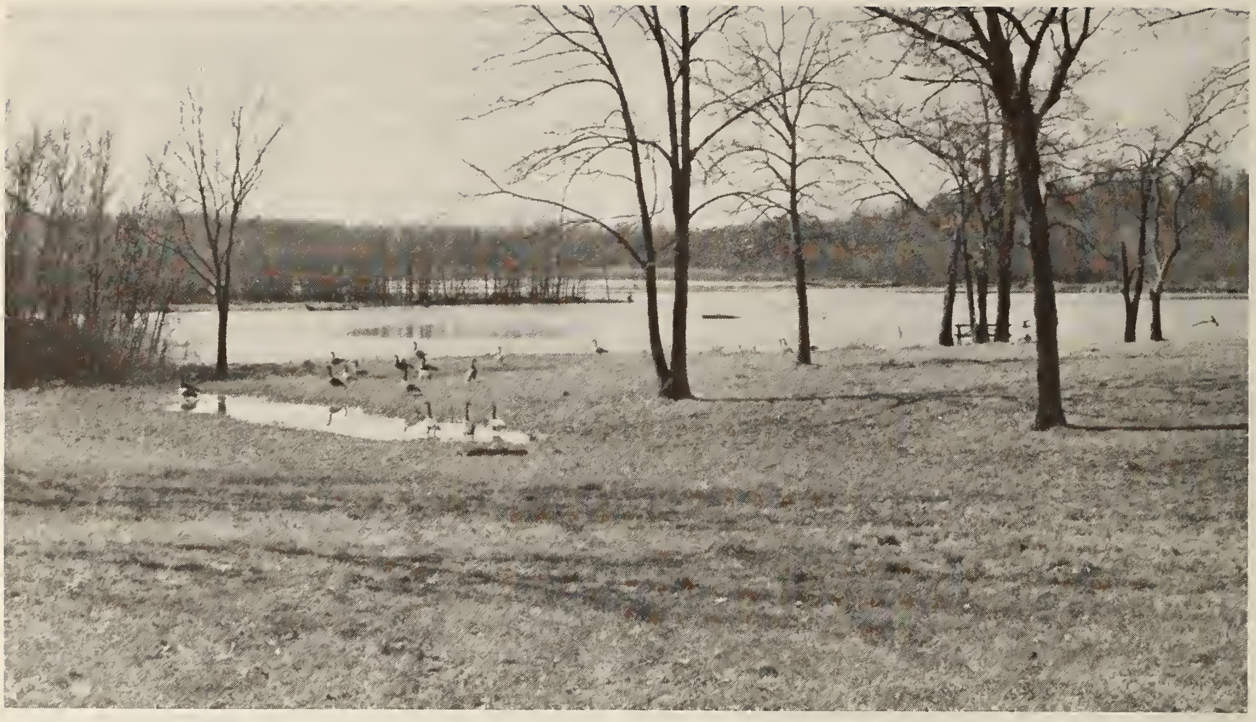

FIGURE 3. - A recreation area and a wildlife refuge in Missouri is now the use of this surface-mined land.

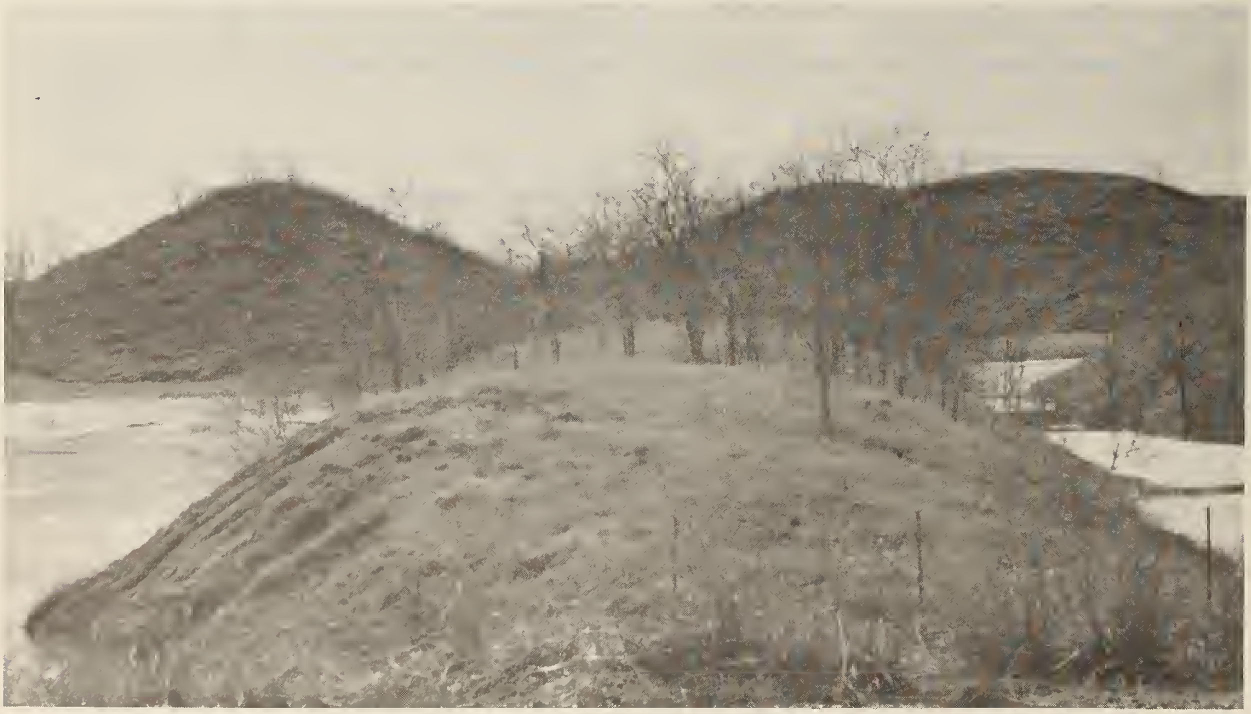

FIGURE 4. - Land mined before compulsory reclamation in Missouri is used for pasture and abounds with wildlife.

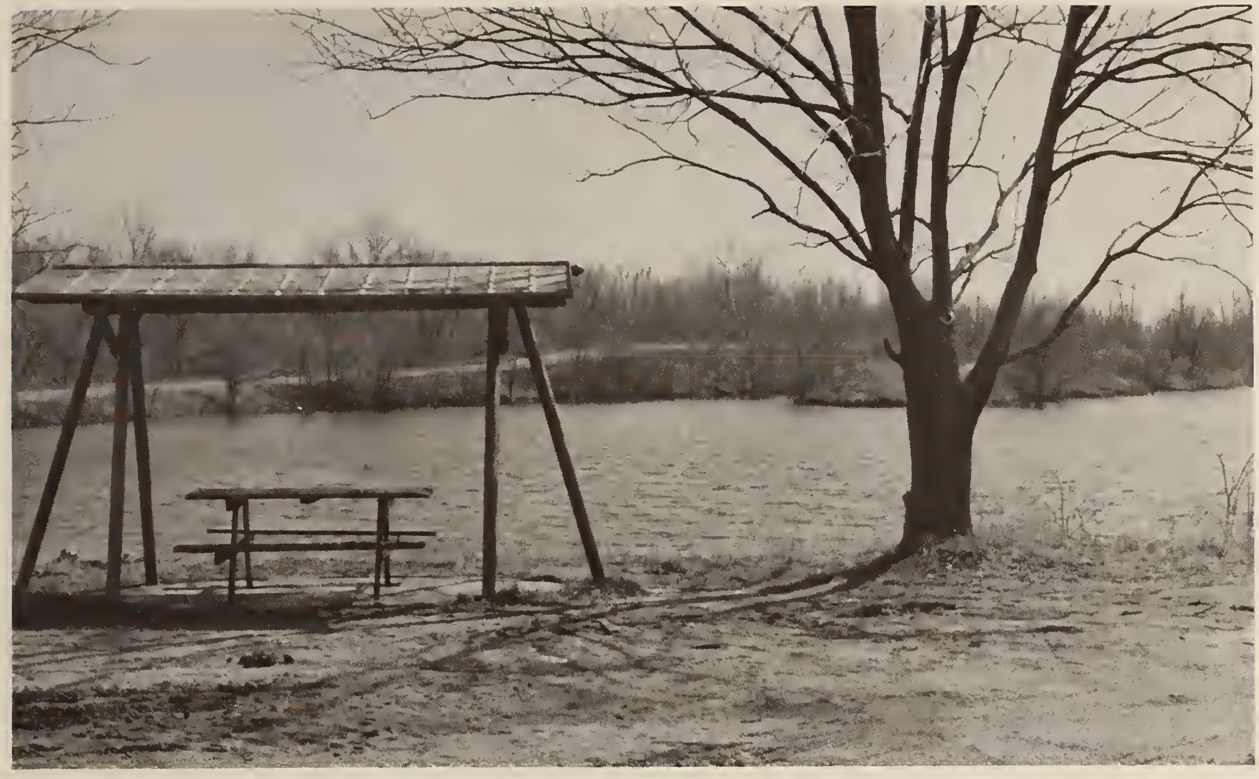

FIGURE 5. - A State recreation area on mined land in Kansas.

distance of 75 feet (fig. 7). Particulars for distances allowed on slopes of less than 25 percent can be found in the Kansas law (9). The law in Missouri (10) permits maximum slopes of 25° and allows up to 25 percent of the disturbed land to be considered ungradable.

Often the coal beneath roads is mined. Figure 8 shows a reclaimed county road in foreground and the original road in background.

With the exception of liming and fertilizing at some locations, no other soil preparation is performed after final grading (fig. 9). Seeding is generally let to contract and is either applied with a drill or broadcast from an aircraft. In the southern part of the region seed species that mature early in summer are used because the hot southerly winds are not conducive to late maturing species. Trees and shrubs were not being planted in Kansas and only on small acreages in Missouri.

Reclamation costs for design, engineering, and overhead; bond and permit fees; backfilling and grading; and revegetation as well as the total reclamation costs for the six mine sites in Region A are shown in table 2 as the cost per acre, per ton of coal produced, and per million Btu.

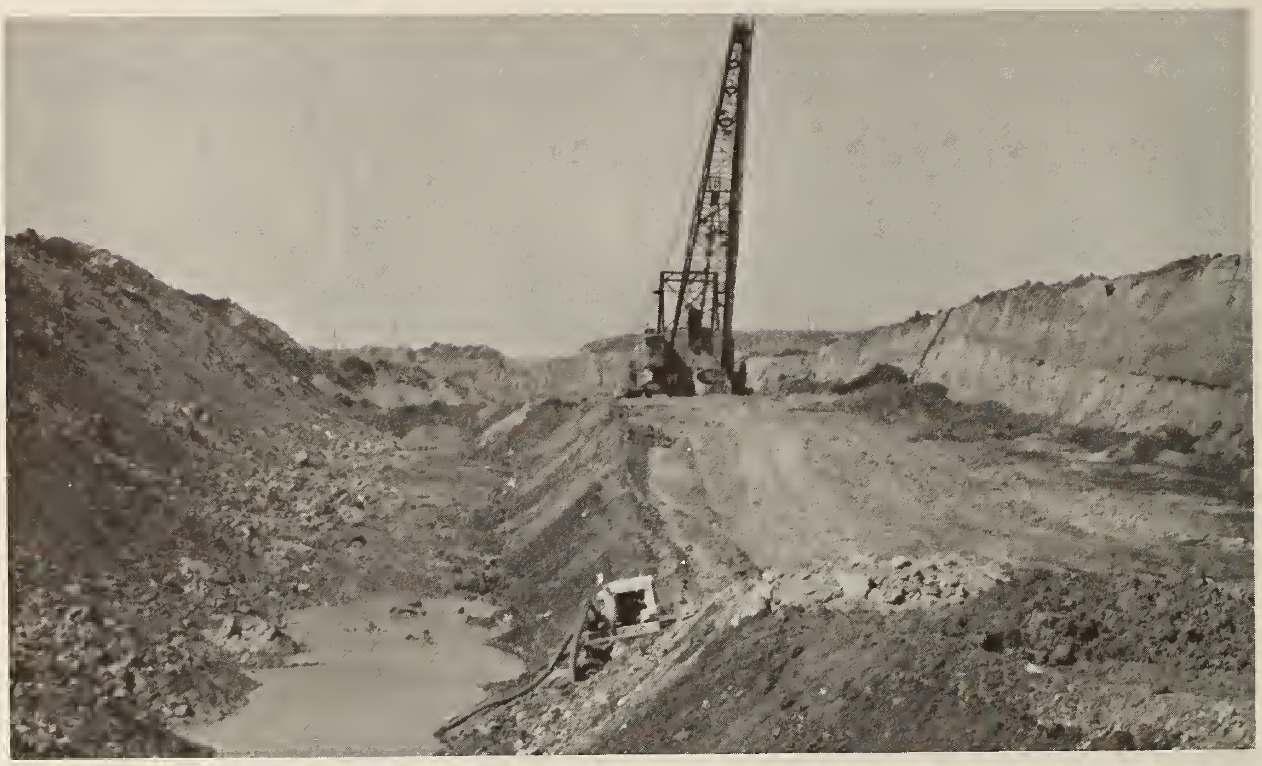

FIGURE 6. - Overburden from above the upper coalbed is spoiled in a manner to allow burial of the parting when the lower coalbed is mined.

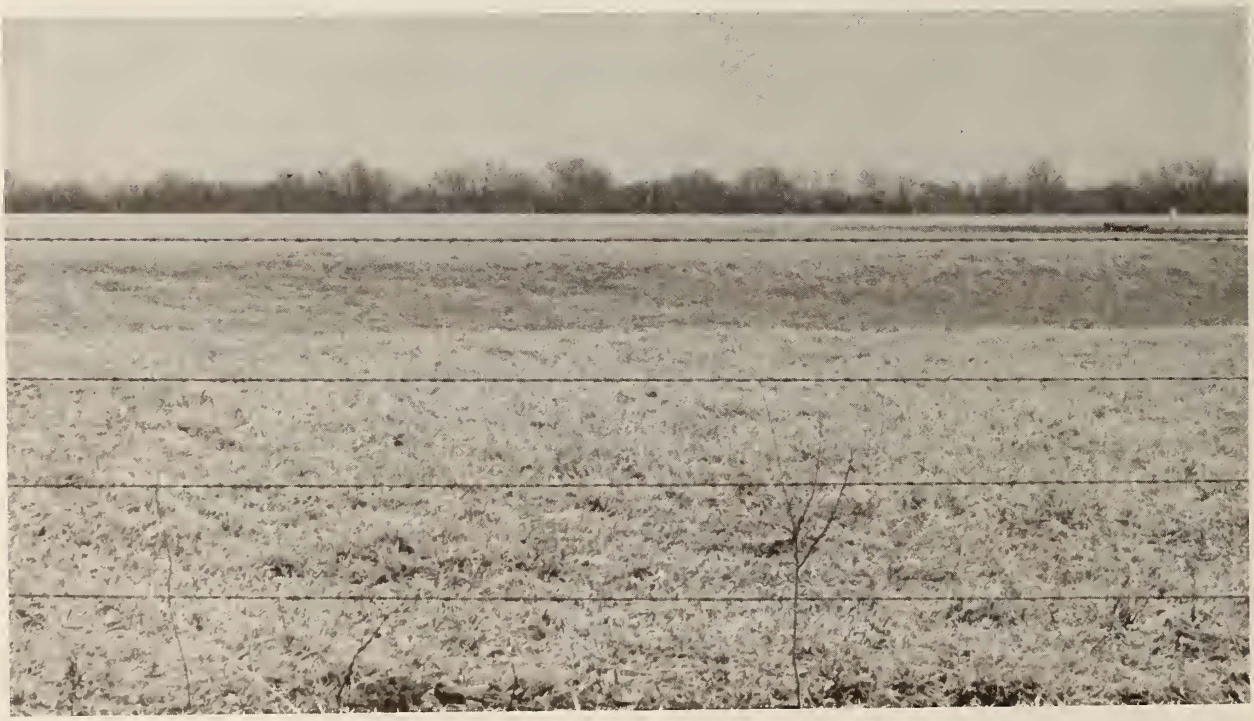

FIGURE 7. - Reclaimed surface-mined land in Kansas.

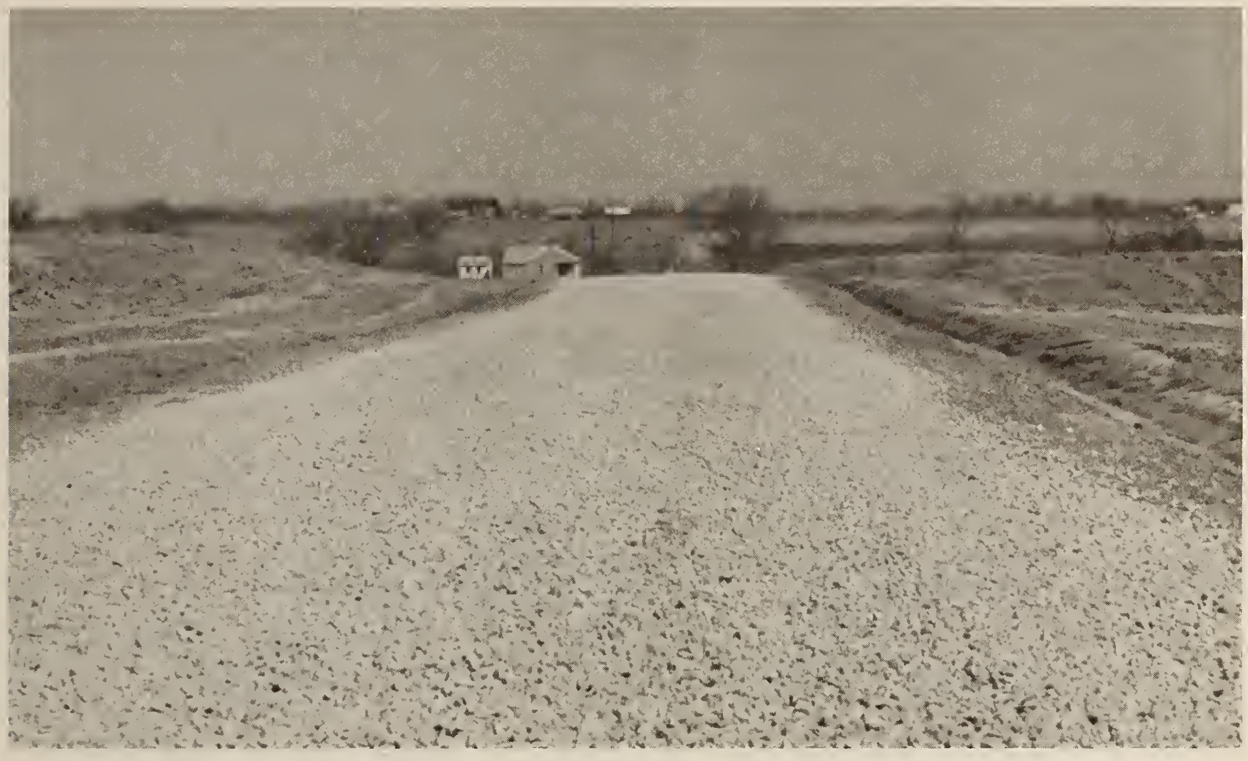

FIGURE 8. - In the foreground a county road has been reclaimed. Unmined land and the original road can be seen in the background.

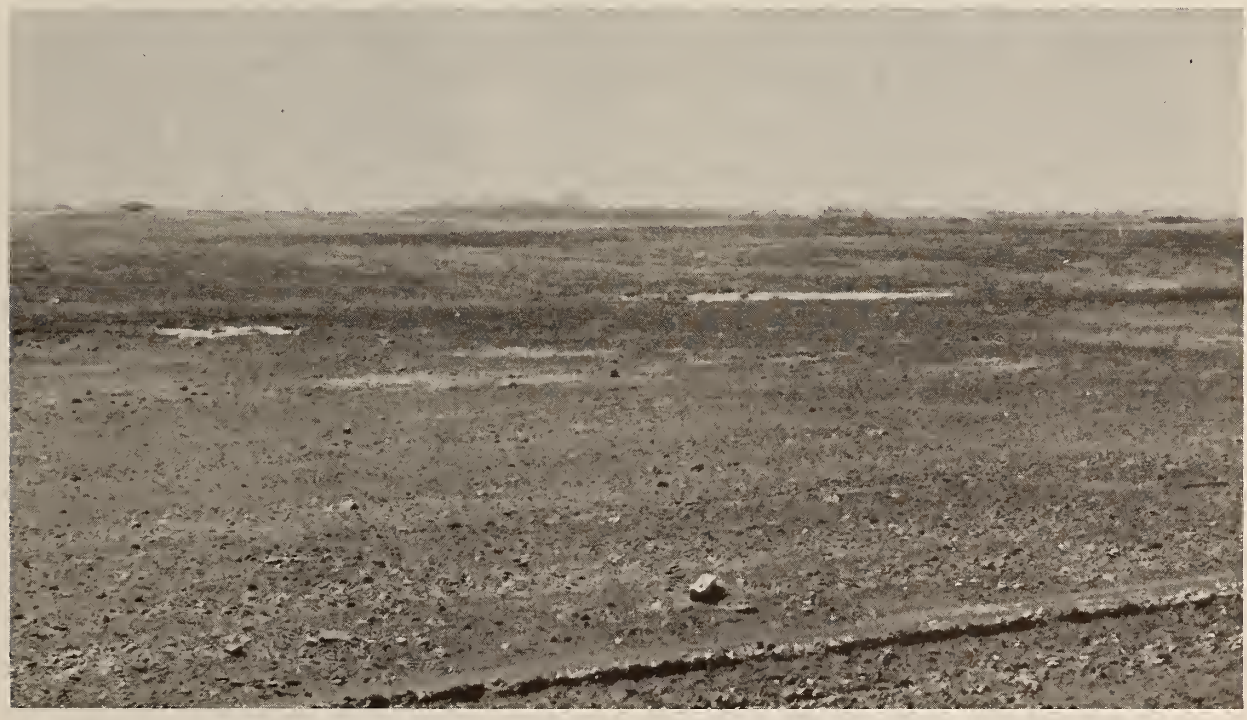

FIGURE 9. - Graded land ready for seeding.

Region B

Region B is the east Texas part of the Gulf coal province (fig 10). In 1975, the output from its four surface lignite mines totaled 11.4 million tons, used primarily to generate electric power. A lesser use is for activated carbon manufacture.

In this part of eastern Texas, rainfall occurs fairly evenly throughout the year. Annual amounts of 40 to 46 inches exceed average potential evapotranspiration causing a humid climate. Mean minimum temperatures in January range from 34° to 38° F, while mean maximum temperatures in July range from 94° to 96° F. Consecutive days exceeding 32° F range from 230 to 260 per year.

The topography is rolling coastal plains broken by broad river valleys and low hills. Elevations seldom exceed 600 feet above sea level. Region B is in an area where prairie grasses and deciduous trees are intermixed. Forestry, ranching, farming, and land management for wildlife are the main land uses. The dominant native grasses are bluestem and Indian grass.

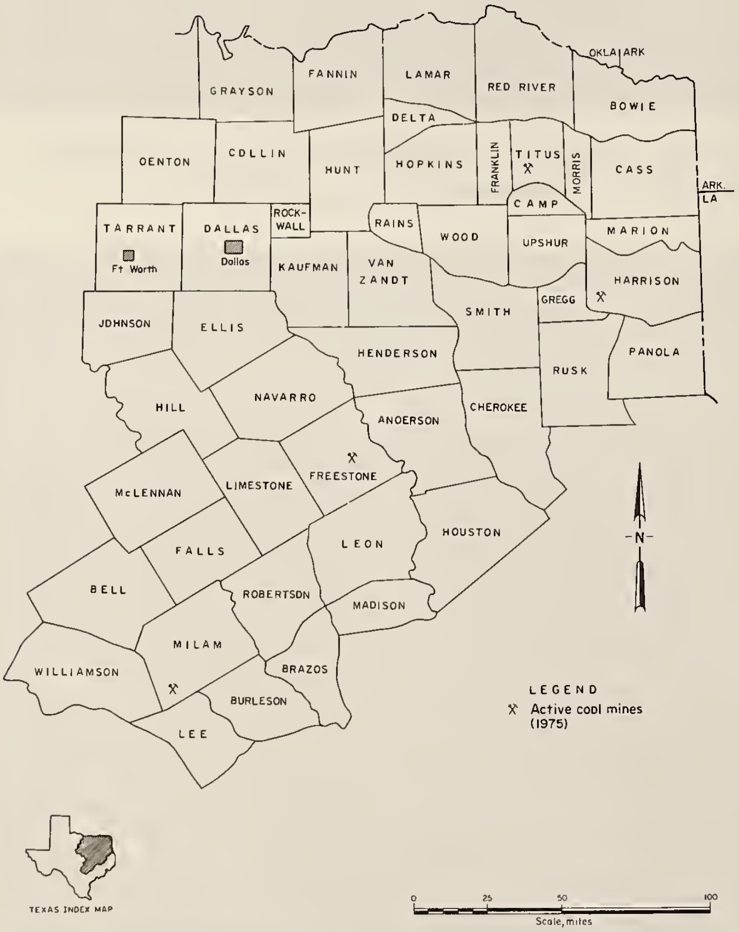

FIGURE 10. - Active coal mines in Texas.

Although one of the active surface mines was opened in 1932, large-scale output did not begin until 1970. All mines are recovering lignite from rocks of the Wilcox Group of Eocene time. Coalbeds vary in thickness, but the average range is from 6 to 8 feet beneath an overburden that averages about 50 feet in thickness. The overburden consists of poorly consolidated sandstone with interbedded shales. Mining depths do not extend below the water table, and permanent streams are avoided.

Water from the pits is settled to prevent siltation of watercourses, but it is not toxic; the pH is similar to that of other waters in the vicinity.

Reclamation of the mined land began with the planning. For example, to reduce the amount of bulldozing required when the spoil is graded, draglines with extra boom length were used so that spoil could be cast in multiple rows rather than forming a single ridge. Topsoil is not salvaged in Texas. It was found that plant nutrients have been leached from the surface but not from the subsurface material. Therefore, the spoil is a better growth medium than the undisturbed land.

Bulldozers and scrapers are used to grade the spoil into gently rolling flatland to be used for rowcrops, hay meadows, or pasture. Occasionally ponds are created to serve as stock-watering tanks.

Spoil is revegetated with coastal Bermuda grass. In the spring of the year, the graded surface is disked and fertilized with a 12 N, 12 P, amd 12 K mixture. Bermuda grass then is sprigged. Hay yielding up to 50 bales per acre is harvested in the fall. The grass is again fertilized the following spring. The second and consecutive years' growth is used for hay, pasture, or both.

On June 20, 1975, the Texas Surface Mining and Reclamation Act was passed. Until the effective date of this act, January 1, 1976, mined-land reclamation was not compulsory in Texas. The costs shown in table 2 were estimated by observing the reclamation before enactment of the Reclamation Act.

Total reclamation costs and the costs for the four categories are shown in table 2 as the cost per acre, per ton of coal produced, and per million Btu.

Region C

In Region C (Arizona, Colorado, and New Mexico), three mine sites west of the Continental Divide were selected. Sites 1 and 2 are typical of the high desert area, and site 3 is characteristic of a mountain area.

Sites 1 and 2 were chosen from the five surface mines operating in the Four Corners area of Arizona and New Mexico (fig. 11). Per mine output for 1975 ranged from less than 500,000 to 6.1 million tons of coal. The coal is low-sulfur subbituminous and bituminous, and it is used for generating electric power.

The Four Corners area consists of a high-desert area receiving an annual average rainfall of from less than 7 inches at the lower elevations to about 12 inches at the higher elevations. The evaporation rate, however, is 5 to 6 times the amount of precipitation. Elevations in the vicinity of the two mines in Navajo County, Ariz., range from about 6,900 to 7,500 feet above sea level. Where mining is done in San Juan County, N. Mex., elevations range from 5,300 to 5,500 feet, and the mine in McKinley County, N. Mex., is at an elevation of about 7,000 feet. Mean minimum temperatures in January, the coldest month, range from 15° to 20° F, and for July, the range is from 50° to 60° F. Mean maximum temperature for the same months range from 36° to 40° F and 84° to 92° F, respectively. Temperature extremes, however, range from subzero in winter to over 100° F in summer. Wind speeds are usually moderate, although frontal winds during the late winter and spring and in advance of summer thunderstorms may exceed 30 mph for several hours. Peak

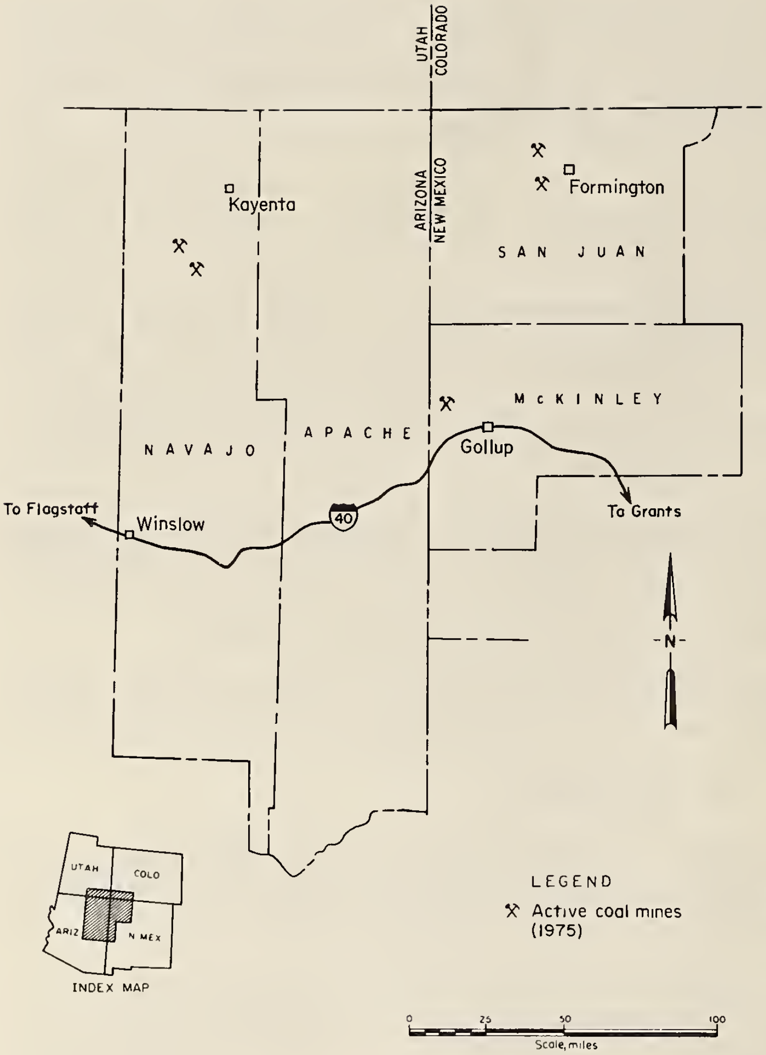

FIGURE 11. - Coal mines in the Four Corners area—Arizona and New Mexico.

gusts of 50 mph are not uncommon. Unprotected land can be eroded by wind and thunderstorm runoff.

Drainage in the mining area in San Juan County, N. Mex., is toward the San Juan River. Immediately south of the river, the terrain is nearly flat with poorly developed drainage (fig. 12), but farther south it is typical desert badland. North of the river, average elevation changes are about the same as they are to the south, but numerous hogbacks, arroyos, and washes dissect the land creating a rough appearance. Drainage in the vicinity of the mine in McKinley County, N. Mex., is toward the southwest, and it has created a terrain that is similar to that north of the San Juan River. Atop Black Mesa, Navajo County, Ariz., intermittent streams flow southwesterly cutting the northwest trending anticlines to form an irregular terrain.

Vegetation is mostly desert grasses spotted with areas of sagebrush. Pinon-juniper woodlands are also prominent, especially on Black Mesa (fig. 13).

Open-range sheep grazing is the predominant land use, but it requires about 130 acres per head per year. Although coal was mined in small quantities by Indians in Arizona as early as 1300 (5), large-scale surface mining only began in the Four Corners area in the 1960's. Area mining is the method used at all mines. One to four coalbeds can be mined in some locations and may range in thickness from 5 to 30 feet.

Overburden thickness seldom exceeds 100 feet, and it consists mainly of siltstone, sandstone, mudstone, and shale, none of which are acid forming. All aquifers are well below the mining depth and, therefore, are not disturbed.

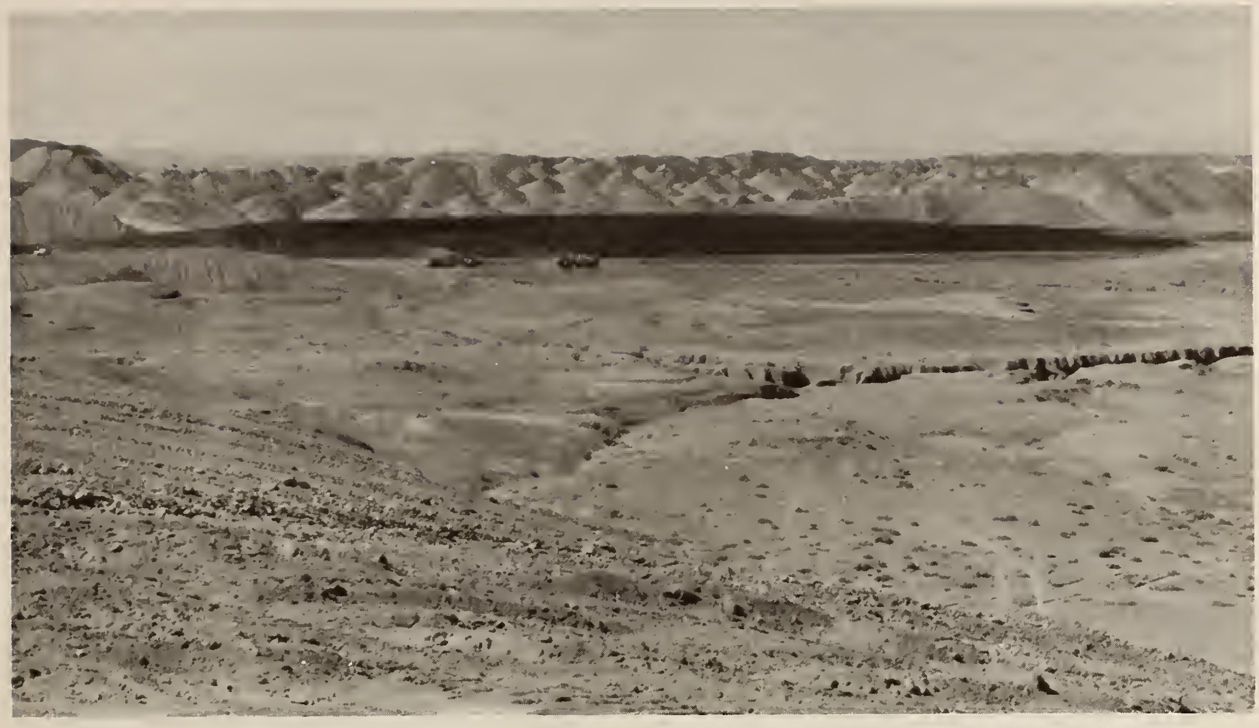

FIGURE 12. - Poorly developed drainage, center, with regraded spoil in foreground and active mine area in the background.

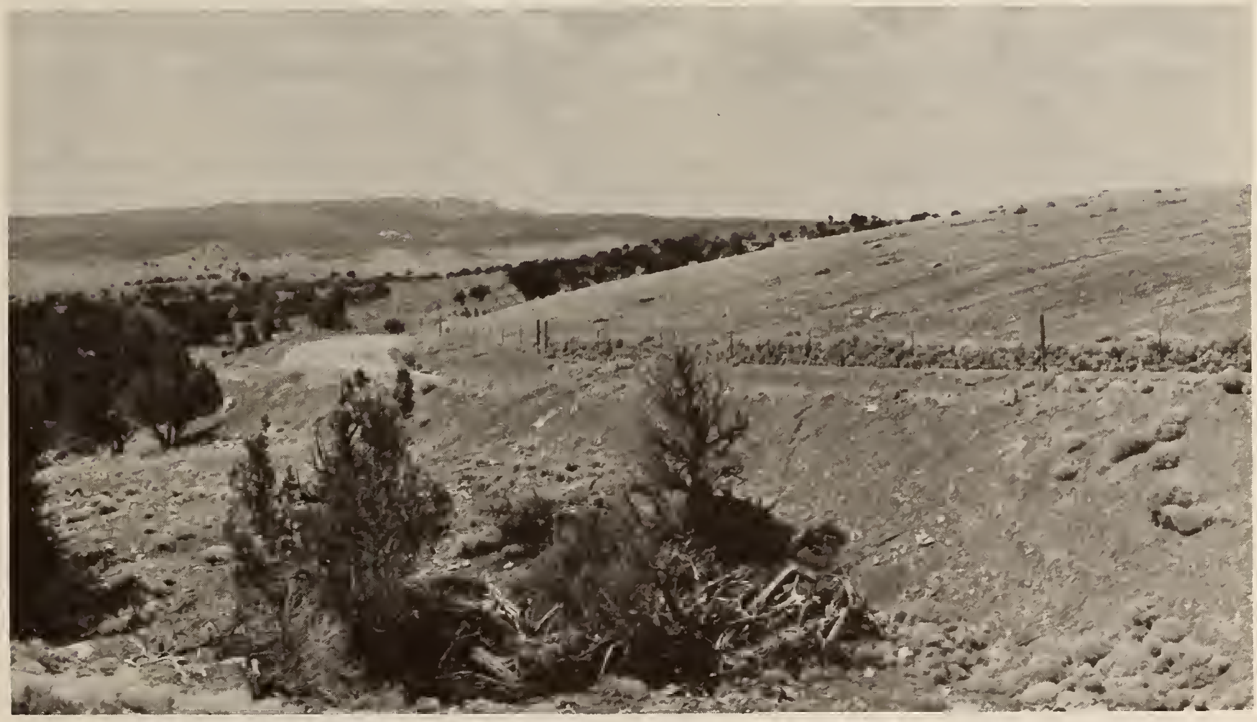

FIGURE 13. - Graded spoil, right center, blends into the natural terrain in the Four Corners area.

The minor amount of surface water that collects in the pits is used in the mining operation.

Reclamation of the mined land at sites 1 and 2 in Region C is still in an experimental stage. Topsoil is almost nonexistent, and where it does exist, it mainly consists of sand. In one operation, salvaged topsoil is spread and provides 6 inches of cover on about one-third of the graded spoil area. Scrapers, bulldozers, and a dragline have been used for topsoil removal and replacement.

Backfilling and grading are generally accomplished with bulldozers; however, various types of graders are being tried for final grading. The finished grade on Indian lands must conform to the specifications in the lease agreement; in New Mexico, the finished grade on railroad and other private leases must conform to the State law (11).

Experiments with soil preparation, seeding, and irrigation are being conducted. Soil preparation mainly consists of mulching to prevent wind erosion. Bottom ash from powerplants and hay are two mulches that are being tried. High wind losses with hay mulch have been experienced. Both native and introduced species of grasses and legumes are seeded, and seeds of some species are expensive. Large tracts, 500 to 600 acres, are irrigated during the first growing season to assist plant starts. Survival, after irrigation has been terminated, is yet unknown.

The average and range of estimated costs for reclamation of sites 1 and 2 are shown in table 2 for different categories: Design, engineering, and overhead; bond and permit fees; backfilling and grading; revegetation; and the total reclamation costs as the cost per acre, per ton of coal produced, and per million Btu.

Site 3 is representative of properties mined by four companies producing low-sulfur bituminous coal from the Yampa coalfield in the mountains of Routt County, Colo. (fig. 14). Combined output for 1975 from these surface operations was 4.1 million tons.

Mean annual precipitation, consisting mostly of snow, ranges from 15 to 20 inches. The median number of consecutive days the temperature is above 32° F at Hayden is 76 but at Steamboat Springs it is only 28. Mean maximum temperatures for January and July range from 28° to 32° F and 72° to 84° F, respectively. Mean minimum temperatures are 0° for January and range between 36° and 44° for July.

In this part of Region C, coal is surface-mined along a series of hogbacks which separate northerly trending valleys that drain into the Yampa River.

Elevations range from about 6,800 to 8,000 feet above sea level.

Flora consists of those grasses, forbs, shrubs, and trees that are common to the montane and foothills zones. It is the type of vegetation that attracts wildlife and is predominantly used for open-range cattle and sheep

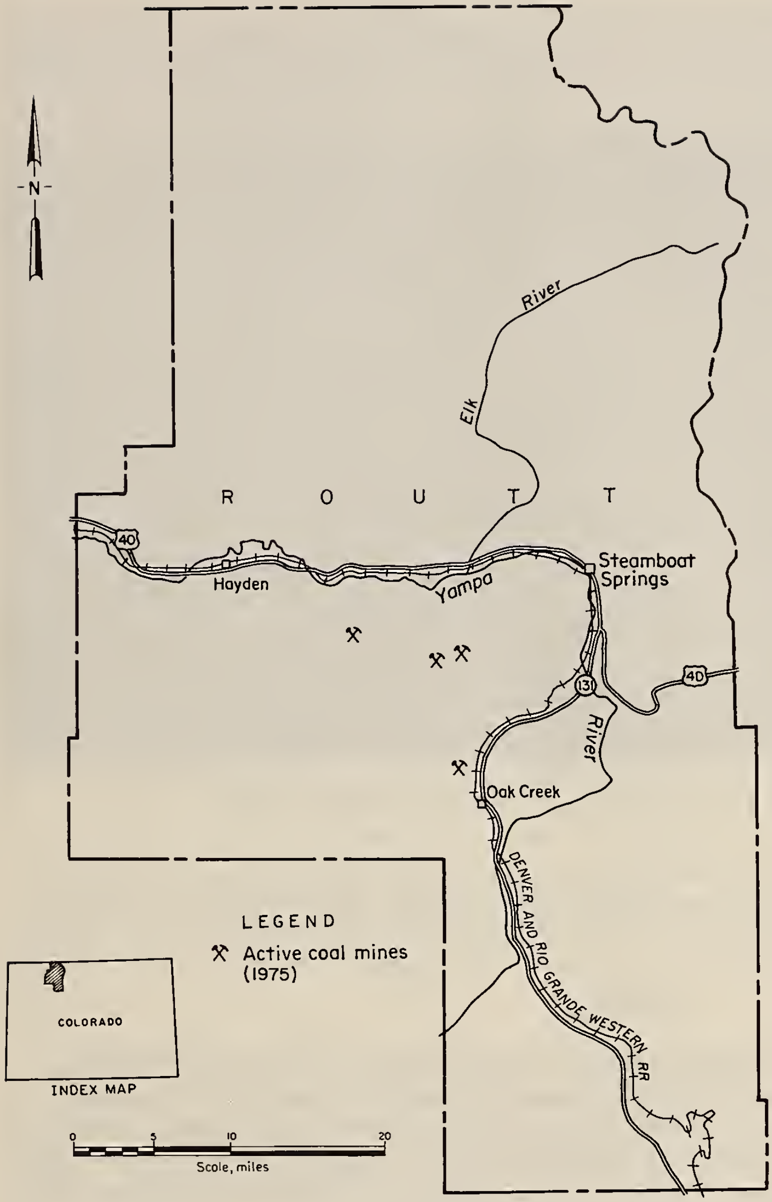

FIGURE 14. - Coal mines in Routt County, Colo.

grazing. Open tracts on the valley floors and some on the slopes and terraces are used for small grain and hay farming (fig. 15).

Coal has been mined in the area of site 3 since the early 1900's. Surface mining began in the 1940's. Area stripping is the method used. Overburden thickness ranges from 30 to 150 feet, and coalbed thicknesses range from 4-1/2 to 10 feet. Reclamation of the mined land began in the 1960's by striking the spoil peaks and ridges, followed by seeding and tree planting. Reclamation has evolved to forming a rolling topography and seeding the graded spoil.

Topsoil, consisting of rock fragments in thin layers of organic material and clay, rarely exceeds 6 inches in thickness, and is nonexistent where rock crops out. The remainder of the overburden is predominantly sandy shale with some interbedded sandstone. The separation of topsoil from overburden was not required until mid-1976.

Spoil is graded to a rolling topography to blend in with the surrounding area. Most of the small boulders that remain on the graded surface are sandy shale that will slake and disintegrate, thus eliminating the need for rock picking. Using conventional farm equipment, the graded spoil is seeded with a mixture of grasses and legumes.

Surface water is diverted and/or pumped from the working areas, but it is not toxic so the excess is allowed to flow into natural watercourses. No aquifers are intersected during the mining.

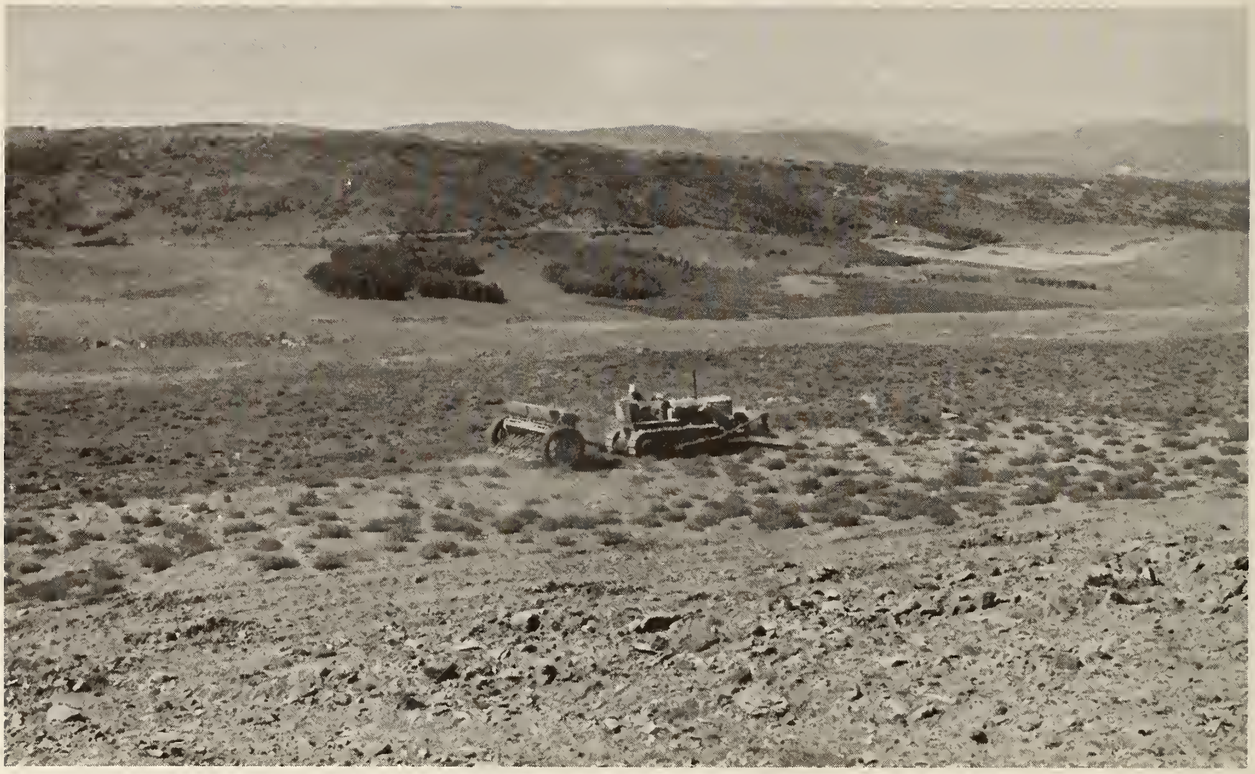

FIGURE 15. - Seeding graded spoil in Yampa Valley, Colo.

The average and range of reclamation costs for mines in site 3 of Region 6 are shown in table 2 as the cost per acre, per ton of coal produced, and per million Btu.

Region D

Region D is the Northern Great Plains coal province in eastern Montana, western North Dakota, northwestern South Dakota, and northeastern Wyoming (fig. 16). The Nation's largest low-sulfur subbituminous coal and lignite resources occur in two large geologic basins, the Williston to the north and east and the Powder River to the south. In addition, a small coalfield, the Bull Mountain, lies west of the Powder River basin.

Although no coal (lignite) has been produced in South Dakota since the 1960's, production from the remainder of the region has increased from 13 million tons in 1970 to 37 million tons in 1975. Over 99 percent of this production has been from surface operations. Proposed production, including expansion of current producers and new operations, is expected to exceed 100 million tons by 1980.

Recent production has been predominantly subbituminous C (8,300 to 9,500 Btu per pound). A lesser amount of lignite (<8,300 Btu per pound) was produced, principally from North Dakota. The predominant use of coal and lignite produced in Region D is fuel for electric power generating plants.

At the time the data were gathered, 23 surface mines were operating in the region (fig. 16). At least three of the mines have been operating since the early 1920's with only brief intervals of no output.

The climate in the region is semiarid, and weather conditions are influenced by altitude and proximity to the Rocky Mountains. Altitudes of the mining operations range from 5,800 feet in eastern Wyoming to less than 2,000 feet in west-central North Dakota. Precipitation is irregular, normally ranging between 12 and 16 inches annually, and usually falling as rain from April to September. Temperature also varies widely for different locations within the region, but the normal range is from subfreezing in the winter to the low 70's in July. Extreme temperatures range from subzero to over 100° F. The average number of consecutive frost-free days ranges from approximately 130 in the southern part of the region to less than 100 near the Canadian border.

The southern or Wyoming part of the region (upper Powder River basin) is a major depression, extremely dissected in places, with spurs, buttes, and terraces capped with shale that was baked by intense heat from burning coalbeds (4). In the Montana part of the Powder River basin, the terrain gradually changes to a broad plain characterized by extensive badlands along the larger streams and by red hills, benches, ridges, and buttes of shale and sandstones. Here, too, deposits of baked shale are common (3). North of the Powder River basin in Montana, and to the east into the Dakotas is the Williston basin, which is larger than the Powder River basin. The terrain in the southwestern part of the Williston basin is similar to the northern part of the Powder River basin. However, the northern and eastern part of the Williston basin is a glaciated area of generally flat to rolling topography.

North of the Powder River basin and west of the Williston Basin is a shallow basin containing the Bull Mountain coalfield. The topography of the Bull Mountain area is similar to that of the northern part of the Powder River basin.

All known coal and lignite deposits in Region D are of Tertiary age (1, 7-8). The Montana deposits occur in the Tongue River Member of the Paleocene Fort Union Formation; North Dakota lignite deposits are in both the Sentinel Butte and Tongue River Members; and in Wyoming, with the exception of the deposits in the Eocene Wasatch Formation in the western part of the Powder River basin, all of the deposits are in the Tongue River Member of the Fort Union Formation. Multiple coalbeds occur throughout the Powder River basin; aggregate thicknesses often exceed 80 feet (fig. 17).

Generally, the coal-bearing formations lie nearly flat; exceptions include formations in the Bull Mountain coalfield that dip up to 30°. Rocks associated with the coal consist primarily of poorly consolidated sandstone and siltstone with minor amounts of shale. Many coal outcrops have ignited and areas thus affected are characterized by the red, baked rocks over the burned coal.

Soils are primarily of the Mollisol order. Vegetation mainly consists of mixed prairie grasses and sagebrush. Trees and shrubs are sparse, occurring only as scattered stands in gullies and valleys.

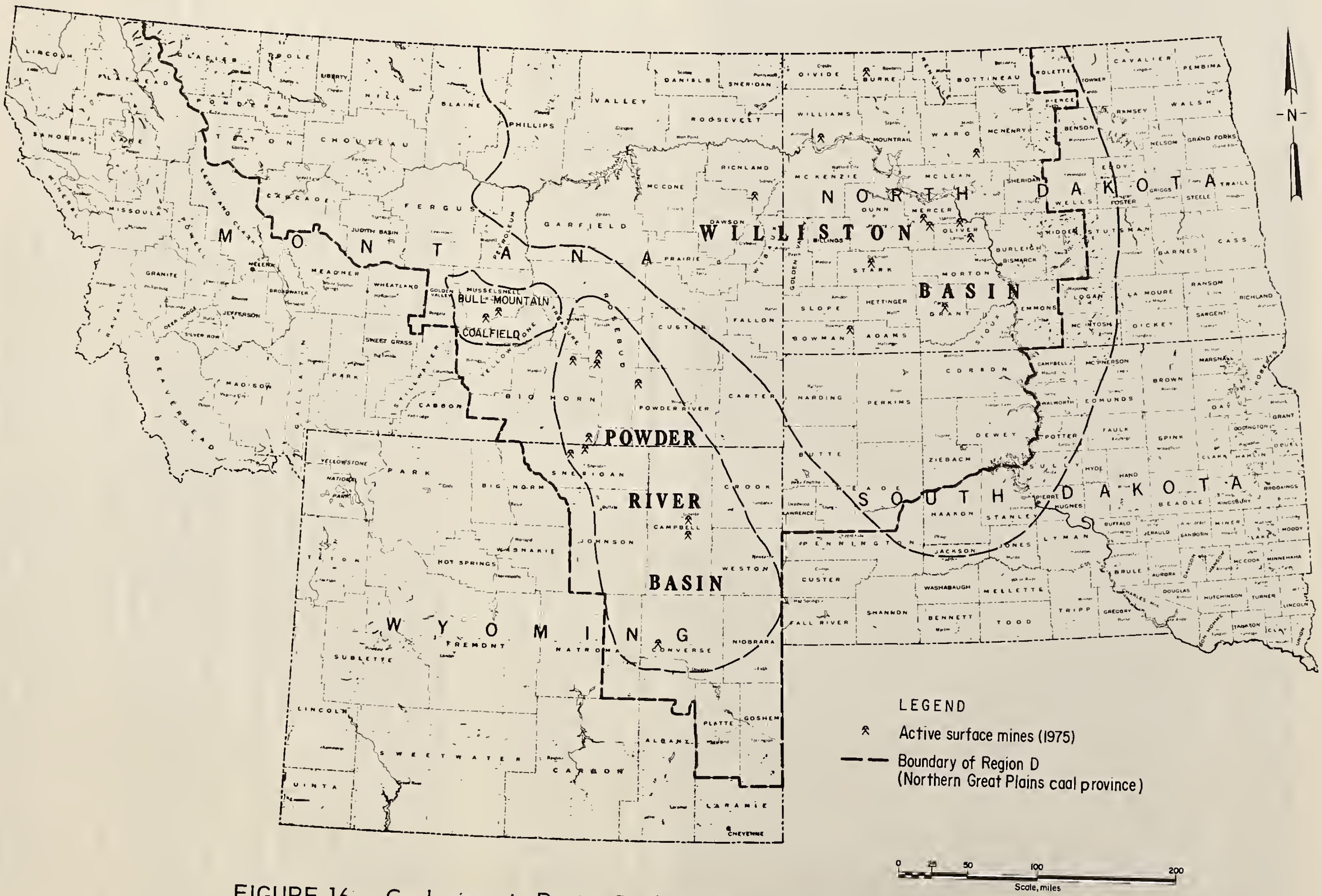

FIGURE 16. - Coal mines in Region D, the Northern Great Plains coal province.

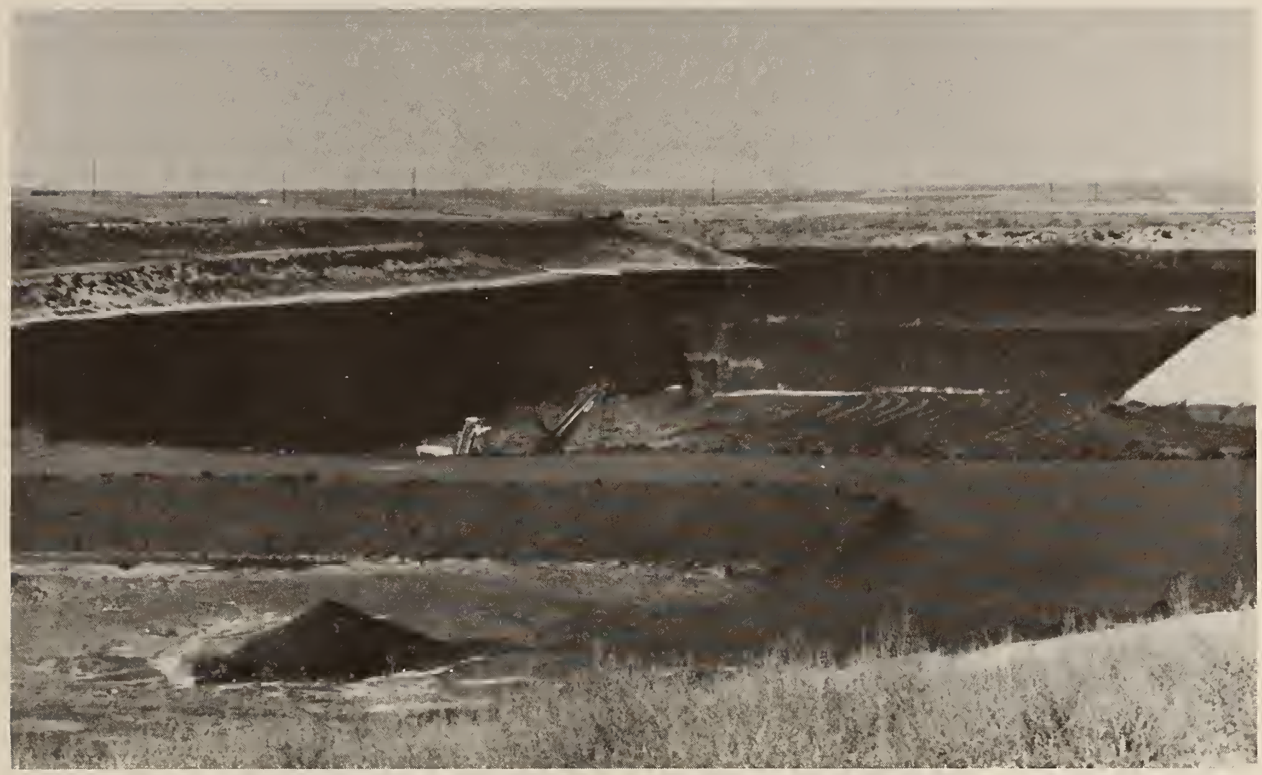

FIGURE 17. - Mining coal from one of the thick coalbeds in Wyoming.

The predominant land use is dryland farming and ranching. Mostly small grains, hay, and cattle are produced. Cultivated lands generally are limited to flood plains and benches of the larger valleys, whereas the higher lands, ridges, and buttes are utilized for grazing.

The average and range of reclamation costs for three area-stripping operations in Region D are shown in table 2. The lower range figures reflect typical or normal costs and do not include specialized reclamation such as plant facility areas, highwall reduction, grading box cut spoil, or backfilling ramp roads. These stages of reclamation had not been reached under the regulations in effect at the time the data were gathered. However, the cost of reducing highwalls, box cuts, spoils, and ramp roads to required slopes was estimated and is reflected in the high range costs presented in table 2.

The percentage breakdown of reclamation costs for each of the sites in Region D is shown in table 3.

Site 1 is a single bed area stripping operation producing over 3.2 million tons of coal annually for power generation. The coalbed has an average thickness of 25 feet. This mining operation affected over 100 acres of land in 1974.

Overburden at site 1 consists of light-colored sandstones, sandy shales, and thin limestones. Topsoil thickness ranges from 0 to 8 feet. Highwalls are from 60 to 85 feet high and must be returned to approximate original contour. The slope of the terrain is variable but averages less than 10° from horizontal.

In compliance with State regulations, topsoil is removed and stockpiled (fig. 18) or placed on graded spoil. To facilitate removal, topsoil is ripped, then removed with scrapers assisted by pusher tractors (fig. 19). Backfilling and grading are done mainly with bulldozers, but scrapers occasionally assist. After topsoil has been spread over the graded spoil, a farm tractor with the necessary equipment is used to disk, harrow, fertilize, and seed the land. Aerial methods also have been used for applying fertilizer.

The estimated cost breakdown for reclaiming this mine site is shown in table 2.

Site 2, an area strip mine, produces about 1.3 million tons of coal annually for power generation. The lignite bed averages 9 feet in thickness. Mining disturbs about 140 acres each year.

Overburden, averaging 45 feet in thickness, consists of soil, shales, clays, and locally soft sandstones. The materials are soft and easily removed by a dragline without the use of explosives. Highwall heights at property or deposit limits may reach 60 feet but average less than 50 feet. As much spoil as possible is cast into a previous cut, but pit configuration often necessitates placing it on undisturbed ground. Although the topography is rolling, the overall slope is relatively flat.

Topsoil is removed and replaced with scrapers assisted by pusher tractors. Both wheeled and crawler-type bulldozers are used for backfilling the hollows between the peaks and ridges, as well as for grading. Soil preparation consists of disking and applying fertilizer. It is followed by an application of various kinds of grass seeds. Conventional farm machinery is used for both soil preparation and seeding.

When property or deposit limits are reached, the highwall must be reduced to an angle not exceeding 35° from the horizontal, and topsoil must be applied to the sloping surface. Leaving some water impoundments in the final cut is optional (fig. 20). All land surface above the water level must be revegetated.

The estimated cost breakdown for reclamation at this mine site is shown in table 2.

Site 3, an area stripping operation, yields over 3 million tons of coal and affects over 80 acres annually. The coal is used as a fuel for electric power generation.

The 40-foot coalbed dips about 4 percent beneath an overburden consisting of limited topsoil overlying coarse, soft sandstones and conglomerates. Intermittently, concretionary structures that are generally ferruginous are found directly overlying the coalbed. The sandstones and conglomerates do not

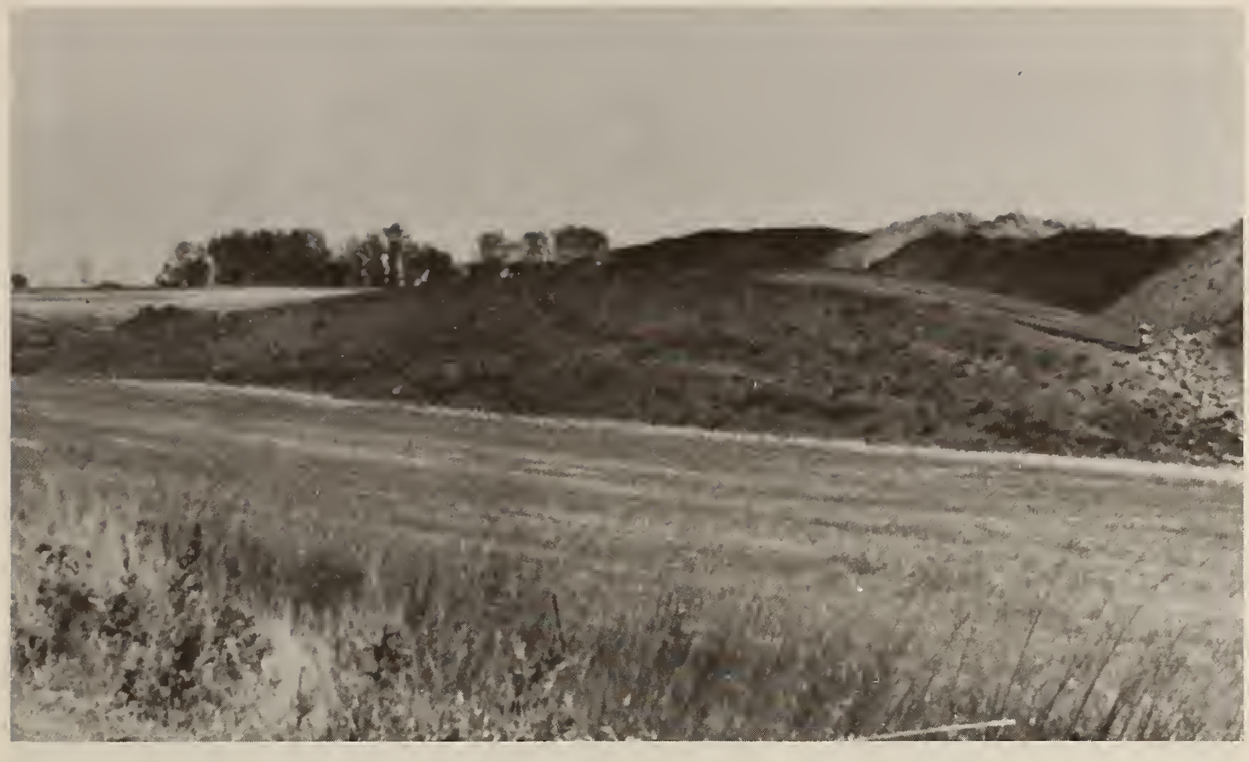

FIGURE 18. - Topsoil has been stockpiled for later use.

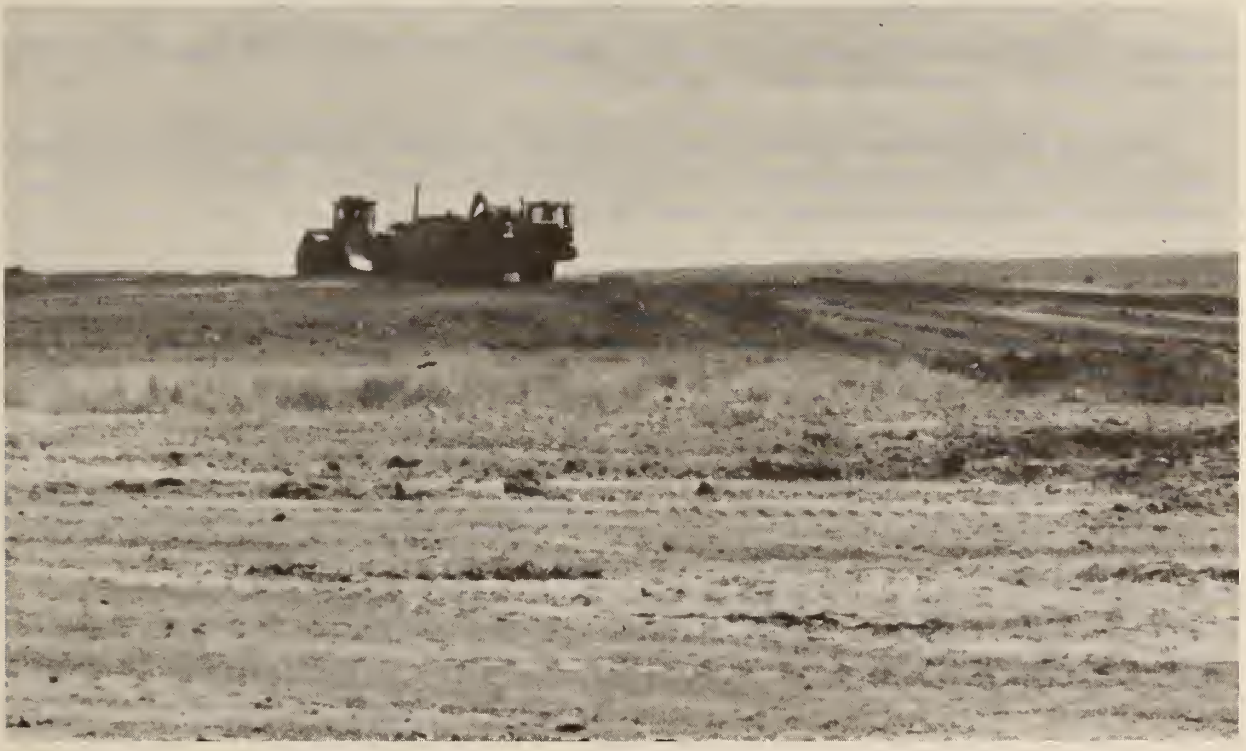

FIGURE 19. - Removing topsoil with a scraper and pusher tractor.

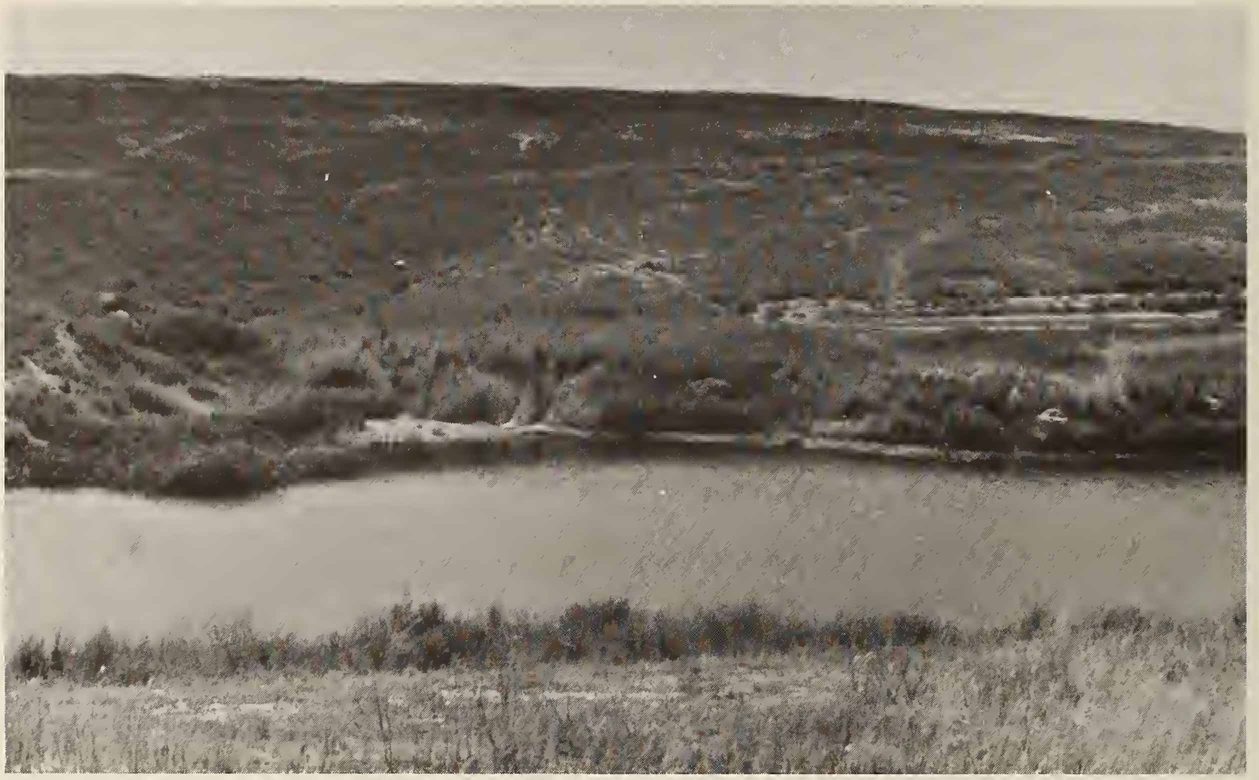

FIGURE 20. - Revegetated spoil along the banks of a lake formed by a final cut.

require blasting for removal, but the concretionary structures do; therefore, all overburden is drilled and blasted.

Mining began along the outcrop and will continue downdip until a highwall height of 140 feet is reached. The highwall will then be reduced to the approximate original contour, a rolling terrain.

Topsoil, seldom exceeding 8 inches in depth, is removed by self-loading scrapers. It is placed directly on graded spoil when available; otherwise it is stockpiled.

Backfilling the hollows between the spoil peaks and ridges and the rough grading is accomplished with bulldozers (fig. 21), occasionally helped by pan scrapers. A motor grader is used for fine grading,

After topsoil is spread on the graded spoil, a contractor using conventional farm equipment prepares and seeds the soil. Soil preparation is mulching and fertilizing; drilling assorted grass seeds follows.

The estimated cost breakdown for reclamation at site 3, Region D, is shown in table 2.

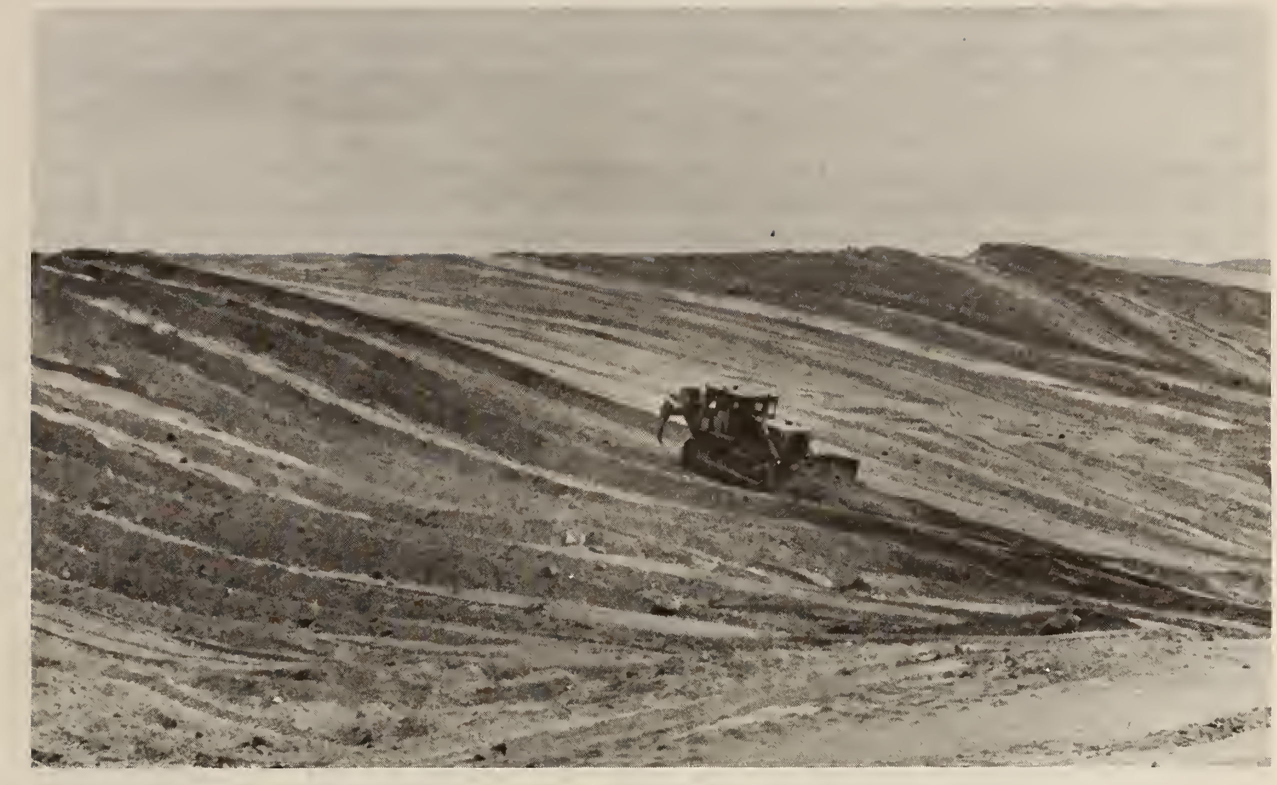

FIGURE 21. - A bulldozer reducing the slope of a spoil pile.

CONCLUSION

Generally, the cost of reclaiming surface-mined land is expressed as the cost per unit of land area (dollars per acre), per unit of weight of coal (cents per ton), or per units of calorific content of the coal (cents per million Btu). Costs are expressed in these ways for various purposes. Dollars per acre is used mainly to determine the amount of bond the operator must post to assure reclamation of disturbed land. Cents per ton of coal or per million Btu can be used to indicate the reclamation cost that the consumer must pay, because it is the consumer, not the landowner, who pays for reclaiming mined land.

In the West, the per-acre cost of reclaiming land disturbed by surface coal mining ranged from less than $1,000 to more than $7,000. The cost per ton ranged from 6 to 84 cents. On a calorific basis, the cost ranged from 4 mills to 5 cents per million Btu.

Many factors contribute to these wide ranges of cost. Factors contributing to per acre cost include, but are not limited to, the following: Accounting procedures, climate, composition of the overburden, mining practices, operator's and/or landowner's preferences, State laws and regulations, terrain before mining, and use of land after mining.

Coalbed thickness is an additional factor that contributes to the wide-cost range when costs are calculated on the basis of cents per ton or per million Btu. The normal criterion for the purchase of steam coal for power generation is its calorific (Btu) content, and nearly all of the surface-mined coal in the West is used for that purpose. Therefore, the cost per million Btu affords the best basis for calculation. The lowest cost per million Btu is for subbituminous coal from thick coalbeds, and the highest costs are for fuels mined from lignite beds of moderate thickness and from thin beds of bituminous coal in Region A.

Variances of costs for engineering, design, and overhead mainly are attributed to accounting procedure.

The climate at the various mine sites is partly responsible for cost variances in all categories, but principally in revegetation. With 35 to 40 inches of precipitation in Region A., almost all final cuts can be reclaimed as ponds or lakes. The high precipitation also assists in reestablishing the vegetation, which results in reducing costs. In Region B, the 40- to 46-inch rainfall and high humidity provide ideal conditions for revegetating the graded spoil. High revegetation costs are experienced where the amount of precipitation is low, especially at those sites in Region C that are experimenting with irrigation.

Composition of the overburden affects costs in all categories. Special handling of overburden increases the cost of planning as well as backfilling and grading costs. Such increases augment the total cost by raising the amount of bond and, in turn, the bonding costs. Increases in reclamation costs are acute where surface rock removal is necessary, but are especially onerous where topsoil is removed and replaced. An example of the latter is evident in Region D. The average reclamation costs in the region ranged from $2,500 per acre where very little topsoil removal is required to $5,050 per acre where up to 5 feet is removed and replaced. Excluding the costs of topsoil movement, the three sites in Region D would average $1,945 per acre for reclamation. Sites 1 and 3 were below this average by 7 and 8 percent, respectively. Site 2 exceeded the average by 14 percent. With the topsoil removal and replacement cost included, as shown in table 2, the average reclamation cost of the three sites is $3,563 per acre. Reclamation cost at site 1 exceeds the average by 42 percent, and the costs at sites 2 and 3 are below the average by 12 and 30 percent, respectively.

Mining practices affect the cost of reclamation. Backfilling and grading costs can be reduced in numerous ways. For example, spoiling overburden in neat uniform rows, devoid of peaks, minimizes the haul distance and quantity of spoil moved in achieving the desired contour. Using a minimum pit width or spoiling so that two ridges are formed also minimizes the haul distance and quantity of spoil moved during reclamation. However, the configuration of the coal or lignite deposit will not always allow uniform spoiling, narrow pits, or two spoil ridges if maximum recovery is to be accomplished from an irregularly shaped deposit. Increased reclamation costs caused by irregular-shaped deposits are found at site 2, Region D.

Occasionally a mine operator or a landowner will want the slope of the reclaimed land at a lesser angle or a different configuration than required by regulation. Such desires require more grading than is ordinarily necessary; hence, the backfilling and grading cost is increased.

Although similarities are found in the various State reclamation laws, each one is different, and it is the differences that cause variations in cost. The most evident are the cost variances between those States that require topsoil removal and replacement and those that do not. Also, cost differences can be related to the depth of topsoil to be salvaged, or to a requirement that a suitable plant growth medium be saved.

Interpretation of the State regulations by either the operator or State authorities can create differences in reclamation costs.

The terrain of the land before mining causes variances in costs. Steeply sloping and flatlands generally cost more to return to the original contour than a rolling topography. Land use after mining is another factor causing variations in reclamation costs. Land to be used for wildlife habitat or pasture does not require as much grading as that to be used for farming.

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